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Geophysical Sciences Laboratory Report No. 65-4

Wave Spectra Estimated from Wave Records Obtained by the OWS WEATHER EXPLORER and the OWS WEATHER REPORTER (III)

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by

L. Moskowitz

W. J. Pierson, Jr.

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Technical Report Prepared for

Office of Naval Research

under contract
Nonr 285(57)

June 1965

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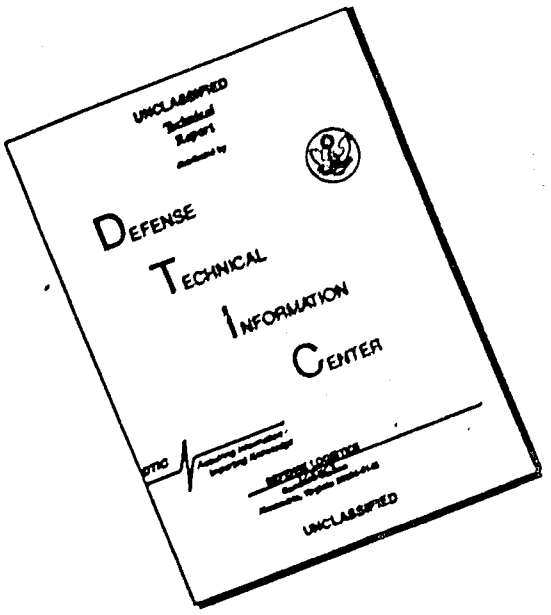

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Introduction

As a part of the problem of developing numerical wave forecasting procedures for the North Atlantic Ocean, selected sequences of the weather maps for the North Atlantic for which wave data were known to be available were studied in detail for the five year period beginning in April 1955 and ending in March 1960. Data from a hurricane in September 1961 have also been analyzed. Certain dates and times of observations were selected for a variety of reasons for study. For these dates and times, the National Institute of Oceanography provided copies of the wave records that were obtained by the OWS Weather Explorer and by the OWS Weather Reporter.

In total, about 800 wave records were provided, and a complete spectral analysis has been made for 390 of these records.

This report is the third and final report (Moskowitz, Pierson, and Mehr, 1962, 1963) to present in tabular and graphical form the results of these analyses. The total number of spectra given is 66. The spectra presented in this volume, labeled JHC 194-219, represent the last of the spectra used in the development of a new spectrum for fully developed seas (Pierson and Moskowitz, 1964). Additional spectra are presented (Bretschneider et al, 1962) which were used but published elsewhere for another purpose. These additional spectra are taken from the above reference and shown on two separate sheets without graphs. Chronologically, they should be placed before the group of spectra denoted by JHB 1-32 which appeared in Vol. II. Volumes I and II will soon be reissued under one cover. The confidence limits and graphical tabulations of these appear in the reference cited above. Beneath each column of spectral values are the total variance $(ft)^2$,

significant wave height (ft), total degrees of freedom, and the average period. These spectra are compatible with all the other published spectra since the analysis procedures were exactly the same.

Analysis procedures

The original wave records varied in length, but almost all of this third set were 15 minutes long. The crest to trough heights of the highest waves in a particular record (uncorrected for calibration effects) varied from a few feet to more than 60 feet in the complete set of records. Bounds were set on each record just above the highest wave crest and just below the lowest wave trough, and the records were read to an accuracy of one part in a thousand (nominally) over this range at an interval of 1.5 seconds throughout the record. Thus a 15 minute record was reduced to a time series of 600 points. Where gaps or irregularities occurred, the records were smoothed by hand as accurately as possible.

The time series of 600 points was then analyzed on the CDC 1604 so as to estimate the energy spectrum of the waves at 60 points over the frequency range from zero to 0.333 cycles per second by means of the procedures given by Tukey (1949) as explained in detail by Blackman and Tukey (1958). The smoothing operation that was used to go from L tu U in the equations of Blackman and Tukey was

$$(1) \qquad U_h = 0.25L_{h-1} + 0.50L_h + 0.25L_{h+1}$$

with suitable corrections at the ends of the range.

The spectral estimates so obtained still had to be corrected for the response of the shipborne wave recorder (Tucker, 1956) and for the introduction of noise in both the original record and in the digitization procedure. The calibration of the shipborne recorder depends on the

ship, and the calibration curves were provided by Mr. D. E. Cartwright for this purpose. The calibration curve for the Weather Explorer is given by Table 1. The calibration curve for the Weather Reporter is given by Table 2. After May 10, 1958, the Weather Reporter made all of the wave observations.

As in another investigation (Bretschneider et al (1962)), it was found that the application of the above calibration curves to the spectra that were originally computed resulted first in a decrease and then a rapid increase in the spectra a high frequencies due to the presence of noise and other irregularities (possibly from nonlinear effects in the original wave records) at the high frequency end of the spectrum. To eliminate this effect, the last part of the spectrum was smoothed by a three point running weighted mean (0.25, 0.50, and 0.25) and then the last ten values were averaged. In the first report of this series, this weighting was carried out as described in that report. The changes in this report should be noted. For comparison the first ten spectra of this report are repeats of the earlier spectra. There is essentially no difference. This average was treated as white noise and subtracted from all spectral estimates. When the reduced values were multiplied by the appropriate calibration curves, the usual result was a fairly smooth spectrum that decreased regularly toward zero values at high frequency. By such a procedure some of the spectral values at high frequency will be negative. These values were automatically set equal to zero in the rest of the computations.

Even with these corrections, there were a few spectra that still became exceptionally large for frequencies greater than about 0.25 cycles per second. This behavior was apparently caused by the

original quality of the record and not by the digitization procedure. These spectra were further modified by arbitrarily setting the calibration curve equal to one above a certain frequency that was selected by inspection of each spectrum.

The result of such a sequence of computations should yield fairly reliable spectral estimates for frequencies ranging from zero to 0.25 cycles per second, but the values at high frequencies should not be used to decide on any features of the high frequency end.

Sample parameter estimates

The spectral estimates that resulted from this sequence of operations were then processed further to obtain some additional useful information. Let U_h^*, for $h = 0, 1, 2, \cdots, 60$, represent the spectral estimates (after subtraction of the noise and multiplication by the calibration for the shipborne recorder) in terms of the resolution of the variance of the wave record into frequency intervals. The following quantities were then also computed and tabulated with each spectrum.

(2) CORR VAR = corrected variance = ΣU_h^*

(3) SIG HGT = $\bar{H}_{\frac{1}{3}} = 2.83\ (2 \Sigma U_h^*)^{1/2}$

(4) AVER T = $\tilde{T} = [\Sigma U_h^* / \Sigma f_h^2 U_h^*]^{1/2}$

(5) TOTAL DF = Total degrees of freedom = $10\ [\Sigma U_h^*]^2 / [\Sigma U_h^{*2}]$

(for 600 points, 60 lags; i.e., 20 degrees of freedom per spectral estimate)

The confidence intervals on the corrected variance and on the significant height are given by

$$\text{Upper 95\% on CORR VAR} = (10^{+1/\sqrt{TDF}})\ \text{CORR VAR} \tag{6}$$

$$\text{Lower 5\% on CORR VAR} = (10^{-1/\sqrt{TDF}})\ \text{CORR VAR}$$

and by

$$\text{Upper 95\% on } \bar{H}_{\frac{1}{3}} = 10^{+1/2\sqrt{TDF}}\ \bar{H}_{\frac{1}{3}} \tag{7}$$

$$\text{Lower 5\% on } \bar{H}_{\frac{1}{3}} = 10^{-1/2\sqrt{TDF}}\ \bar{H}_{\frac{1}{3}}$$

in terms of the total degrees of freedom (TDF) to a high degree of accuracy since the total degrees of freedom are large.

The corrected variance, the significant height, and the total degrees of freedom are relatively insensitive to change in the noise level and in the high frequency behavior of the spectrum. However, the average period can properly be viewed with caution.

The winds at the ship at the time of observation are also given to the nearest five knots as read directly from weather maps when available.

Explanation of tables and graphs

The body of this report consists of supplementary tables, of tables that give the appropriate results for each of the original wave records, and of graphs of each of the estimated spectra along with the confidence intervals on the spectra.

The supplementary tables consist of Tables 1 through 5. Tables 1 and 2 have been described above.

Table 3 gives either the on station position of the ship, A. I, J, or K, or the latitude and longitude of the ship if it is going on or off station. The speed and direction of the ship are given.

Position A corresponds to 62°N, 33°W.

Position I corresponds to 59°N, 19°W.

Position J corresponds to 52.5°N, 20°W.

Position K corresponds to 45°N, 16°W.

If the record was not 15 minutes long, less than 600 points were read. For these records, Table 4 gives the actual number of points used and the corrected total degrees of freedom. A correction to the upper and lower confidence limits, which would be quite small, would also be needed to be exact.

Table 5 consists of date, time and wind speed for each record of the three reports. The wind speeds were extracted from the logs of the weather ships and are recorded to the nearest knot. These wind speeds should be considered to be the most accurate available for the data at hand.

Spectral tabulations

A tabulated spectrum can be interpreted as follows:

1a) Supplementary data for each spectrum consist of the date, hour, wind speed, total degrees of freedom, average period, significant height, corrected variance, noise level, and record number. The confidence limits for the height according to equation (7) are given. A zero wind speed represents an unreported wind speed at the time of the observation as read from synoptic charts.

1b) In the first column, the spectral lag numbers (H) are given.

2) In the second column (FRE) the frequency according to the equation $f = H/180$ (sec^{-1}) is given.

3) In the third column (UNIT = FT^2), the spectrum as computed from the original data is given in units of $(ft)^2$.

4) In the fourth column (FILTERED), a smoothing operator for $H > 40$ is applied. It is actually

$$F_H = 0.25U_{H-1} + 0.50\,U_H + 0.25\,U_{H+1}$$

(where F = Filtered, and U = Original Tukey Estimate).

5) In the fifth column (LESS NOISE), the noise level shown at the top is subtracted from each estimate.

6) In the sixth column (CORR FT 2), the LESS NOISE column is multiplied by the calibration curve for the shipborne record according to either Table 1 or Table 2. If this column agrees with the previous column, at high frequencies, the calibration curve has been arbitrarily set equal to one to avoid extreme values at high frequency.

7) In the last two columns, the upper and lower 95% and 5% confidence bounds are shown.

The format has been changed so that the numbers will be larger and more legible.

Only the spectral values are given from the report by Bretschneider et al. (1962) so as to put all of the available data in one convenient reference.

The graphs of the spectra

The plot that accompanies the spectral tabulation shows the spectrum and the 95% and 5% confidence bounds. A histogram that can be plotted directly by the machine has been used to simplify the presentation. The asterisks represent the upper and lower bounds. The solid

portion represents the outline of the spectrum. The scale is chosen so that the highest 95% confidence value is at the top of the graph and the vertical axis of the coordinate system shows the spectral values for that spectrum in units of $(\text{feet})^2$. The scales change with each spectrum and comparisons between spectra by means of the graphs should be made cautiously.

Availability on magnetic tape

The procedures used to carry out the spectral computations necessitate the use of the digitized wave records. If the spectra are to be computed only once this procedure is satisfactory. If further operations or recalculations of the spectra are to be performed, the use of the digitized wave records can be eliminated. The use of the raw spectra (shown in column three of the tabulated spectra) reduces the amount of input data considerably and hence, also speeds up the computer operations. The raw spectra of all the records presented in this report, the previous two reports, and the paper by Bretschneider et al (1962) are available on magnetic tape. For those who may find further use of the raw spectra, additional copies of the tape can be made available.

Acknowledgments

We wish to thank the National Institute of Oceanography of the United Kingdom for providing us with the wave records. Dr. J. Darbyshire sent some of the records to us from South Africa. Mr. D. E. Cartwright and Mr. L. Draper were most helpful in assembling other records at N. I. O. having them copied and forwarding the records to us. The records were digitized at Johns Hopkins University and at the Davidson Laboratory of Stevens Institute of Technology.

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Tucker, M. J. (1957): A ship-borne wave recorder. Trans. Inst. Naval Arch., London, 98, 236.

Tukey, J. W. (1950): The sampling theory of power spectrum estimates. Symposium on Applications of Autocorrelation Analysis to Physical Problems. Woods Hole, Mass., 13-14 June, 1949, pp. 47-67.

Table 1. Calibration factors for the Weather Explorer. (Vector A)

1.0000					
1.0000	1.0000	1.0000	1.0000	1.0000	1.6157
1.3740	1.2452	1.1746	1.1399	1.1291	1.1343
1.1547	1.1870	1.2304	1.2845	1.3504	1.4277
1.5193	1.6241	1.7444	1.8828	2.0415	2.2243
2.4349	2.6765	2.9523	3.2725	3.6414	4.0714
4.5654	5.1490	5.8190	6.6136	7.5383	8.6338
9.9169	11.4459	13.2691	15.4245	18.0095	21.1086
24.8366	29.3522	34.8079	41.4485	49.5464	59.4548
71.5502	86.5947	105.1503	128.1186	156.7723	192.5202
237.3987	293.8682	365.1736	455.5306	570.2699	716.8705

Table 2. Calibration factors for the Weather Reporter. (Vector B)

1.0000					
1.0000	1.0000	1.0000	1.0000	1.0000	1.5755
1.3277	1.1908	1.1099	1.0630	1.0375	1.0257
1.0260	1.0350	1.0514	1.0633	1.1034	1.1384
1.1805	1.2280	1.2817	1.3424	1.4105	1.4871
1.5731	1.6684	1.7736	1.8918	2.0229	2.1704
2.3321	2.5169	2.7181	2.9479	3.2018	3.4899
3.8088	4.1715	4.5826	5.0408	5.5616	6.1512
6.8201	7.5845	8.4517	9.4439	10.5785	11.8784
13.3689	15.0856	17.0596	19.3530	22.0055	25.0761
28.6529	32.8206	37.6868	43.3807	50.0432	57.8872

Table 3. Position and speed of ship for each record.

Record No.		Position	Heading	Speed (kts)
JHC	194	I	215°	1
	195	I	250°	1
	196	I		Stopped
	199	I	310°	1
	201	I	320°	1/2
	203	I	310°	1/2
	204	I	340°	2
	205	I	350°	2
	208	I		Stopped
	209	I		Stopped
	212	I		Stopped
	217	I	180°	2
	218	I	250°	1
	219	I	240°	1

Table 4. Data on short records for which less than 600 points were available.

Record No.	No. of points	Original TDF	Corrected TDF
JHC 197	586	197	192
198	590	192	189
200	590	209	206
202	590	193	190
206	490	166	136
207	420	169	118
210	500	199	166
211	510	221	188
213	570	187	178
214	540	198	178
215	570	171	162
216	590	203	200

Table 5. Master table of record numbers, dates, times and wind speeds extracted from the log of the weather ships. (Parts I and II)

Record #		Date	Hour	Wind speed	Record #	Date	Hour	Wind speed
DL	1	19/1/58	0	28	30		3	30
	2		6	28	31	27/10/58	0	22
	3		12	30	32		9	33
	4		18	36	33		15	34
	5	20/1/58	0	30	34	27/10/58	21	30
	6		6	34	35	28/10/58	9	32
	7		15	35	36		15	33
	8		21	30	37		21	33
	9	21/5/58	0	38	38	29/10/58	3	32
	10		6	37	39		9	29
	11		12	28	40		18	30
	12		18	28	41	30/10/58	0	27
	13		21	26	42		6	13
	14	22/1/58	3	20	43	17/1/59	6	25
	15	24/4/58	3	36	44	16/1/59	9	16
	16		6	40	45		15	22
	17		12	40	46	7/11/59	21	40
	18		15	35	47	7/11/59	12	38
	19		18	35	48		15	40
	20		21	36	49		18	35
	21	25/4/58	0	36	50	8/11/59	0	55
	22		3	30	51		6	56
	23		6	33	52		12	38
	24		9	36	53		15	37
	25		12	43	54		21	35
	26		15	42	55	9/11/59	0	35
	27		18	35	56		6	40
	28		21	33	57		12	28
	29	26/4/58	0	30	58		18	28

Record #	Date	Hour	Wind speed	Record #	Date	Hour	Wind speed
59	10/11/59	0	30	89		12	25
60		6	35	90		15	25
61	11/9/61	21	7	91		18	23
62	12/9/61	3	10	92		21	23
63		6	11	93	3/10/59	0	23
64		9	11	94		3	27
65		12	10	95		12	9
66		15	11	96		15	6
67	12/9/61	18	10	97	25/7/59	0	26
68		21	8	98		3	24
69	13/9/61	0	8	99		6	25
70		3	8	100		9	25
71		6	8	101		12	27
72		15	9	102		15	27
73	[none]			103		18	23
74	14/9/61	0	7	104		21	23
75		6	5	105	26/7/59	0	20
76	30/1/60	18	33	106	6/4/57	6	30
77		21	42	107		12	28
78	31/1/60	0	43	108		15	30
79		3	39	109		18	28
80		6	48	110		21	26
81		9	41	111		0	21
82		12	40	112	7/4/57	3	23
83		15	40	113		12	25
84		18	36	114		18	30
85		21	40	115	8/4/57	3	30
86	1/2/60	0	35	116		12	21
87		6	12				
88	2/10/59	9	23				

Record #		Date	Hour	Wind speed	Record #	Date	Hour	Wind speed
JH	1	17/1/59	12	35	28	29/1/59	0	40
	2		9	33	29		6	35
	3		15	35	30		12	34
	4		18	34	31		18	38
	5		21	31	32	24/1/59	3	35
	6	18/1/59	0	23	33		6	38
	7		3	22	34	24/1/59	9	45
	8	28/3/59	12	19	35		12	30
	9		18	31	36		15	32
	10	29/3/59	0	37	37		18	32
	11		6	37	38		21	21
	12		12	27	39	25/1/59	0	16
	13		9	27	40		3	19
	14		15	29	41	18/12/58	12	40
	15		18	27	42		18	42
	16		21	27	43	19/12/58	0	40
	17	30/3/59	0	29	44		6	27
	18		3	27	45		12	41
	19		9	21	46		18	39
	20	27/1/59	18	22	47		21	48
	21	28/1/59	0	34	48	20/12/58	0	50
	22		6	27	49		3	50
	23		9	40	50		6	47
	24		12	50	51		9	45
	25		15	48	52		15	41
	26		18	50	53		21	47
	27		21	50	54	21/12/58	0	43

Record #		Date	Hour	Wind speed	Record #		Date	Hour	Wind speed
JHB	1	22/12/59	0	35	17		25/12/59	0	43
	2		6	40	18			6	21
	3		12	45	19			12	19
	4		15	40	20			15	25
	5		18	50	21			18	25
	6		21	52	22			21	22
	7	23/12/59	0	55	23		26/12/59	0	37
	8		3	52	24			6	23
	9		6	43	25			9	22
	10		9	45	26			12	22
	11		12	45	27			15	30
	12		21	40	28			21	18
	13	24/12/59	3	37	29		27/12/59	3	23
	14		6	32	30			9	28
	15		12	20	31			15	25
	16		18	18	32			21	23

Record #		Date	Hour	Wind speed	Record #		Date	Hour	Wind speed
JHC	1	23/11/56	12	20	31		8/6/55	3	22
	2		15	32	32			12	26
	3		18	46	33			15	25
	4		21	41	34			21	22
	5	24/11/56	0	40	35		9/6/55	0	17
	6		3	38	36			3	16
	7		6	38	37			6	26
	8		9	40	38			12	45
	9		15	36	39			18	42
	10		18	35	40			21	47
	11	25/11/56	0	40	41		9/4/55	0	45
	12		3	42	42			3	41
	13		9	38	43			6	35
	14		12	35	44			9	27
	15	19/9/55	3	21	45			15	27
	16		9	21	46			21	22
	17		15	17	47		9/3/58	3	18
	18		21	17	48			6	20
	19	20/9/55	3	21	49			0	28
	20		6	25	50		6/11/56	18	34
	21		15	21	51		7/11/56	0	39
	22	21/9/55	0	19	52			6	28
	23		3	19	53			9	28
	24		12	27	54			12	28
	25	7/6/55	0	19	55			15	30
	26		6	22	56			21	32
	27		9	22	57		8/11/56	0	32
	28		14	20	58			3	30
	29		18	24	59			6	18
	30		21	25	60			12	20

Record #	Date	Hour	Wind speed	Record #	Date	Hour	Wind speed
JHC 61	19/6/56	0	20	91		15	39
62		9	15	92		21	39
63		14	20	93	22/3/56	3	37
64		18	19	94		9	19
65	20/6/56	0	20	95		15	17
66		3	18	96		18	21
67		6	19	97	3/11/55	18	28
68		9	20	98	4/11/55	0	28
69		12	19	99		6	36
70		18	15	100		9	48
71	10/5/56	12	24	101		12	50
72		18	38	102		18	28
73	11/5/56	0	43	103		21	22
74		3	43	104	5/11/55	3	35
75		6	44	105		6	32
76		9	40	106		15	30
77		12	42	107		21	35
78		14	41	108	6/11/55	0	24
79		15	40	109		6	19
80		18	45	110	22/5/57	6	15
81		21	38	111		12	19
82	12/5/56	0	30	112		15	18
83		3	30	113		18	20
84	20/3/56	18	29	114		21	23
85		21	39	115	22/5/57	0	25
86	21/3/56	0	29	116	23/5/57	3	27
87		3	35	117		6	25
88		6	35	118		9	21
89		9	37	119		15	14
90		12	37	120	16/4/58	12	20

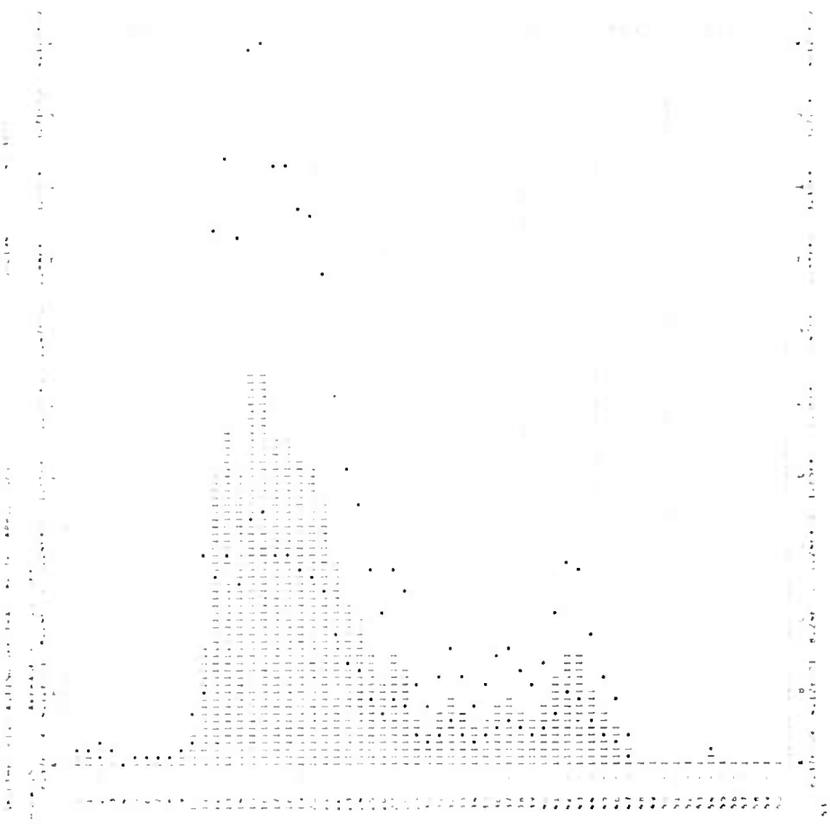
Record #		Date	Hour	Wind speed	Record #	Date	Hour	Wind speed
JHC	121	16/4/58	18	24	153		12	40
	122	17/4/58	0	23	154		15	30
	123		6	23	155		18	30
	124		12	22	156	6/6/59	0	40
	125		18	24	157		3	41
	126	18/4/58	3	18	158		6	48
	127		6	24	159		9	41
	128		12	25	160		12	41
	129		18	28	161		15	36
	130		21	29	162		18	36
	131	19/4/58	3	32	163		21	34
	132		9	30	164	7/6/59	3	25
	133		15	23	165	11/12/55	3	47
	134		21	23	166		9	45
	135	10/12/58	0	28	167		12	43
	136		3	38	168		15	36
	137		6	34	169		18	10
	138		9	40	170		21	10
	139		12	44	171	12/12/55	0	10
	140		15	50	172		3	17
	141		18	52	173		9	15
	142		21	36	174		15	20
	143	11/12/58	0	30	175	13/12/55	0	15
	144		3	20	176		9	16
	145		6	18	177		15	10
	146		15	46	178	14/12/55	0	16
	147		18	35	179		6	19
	148		21	47	180		12	18
	149	12/12/58	0	40	181		18	14
	150		3	32	182	15/12/55	0	5
	151		6	40	183		6	0
	152		9	38	184		18	12

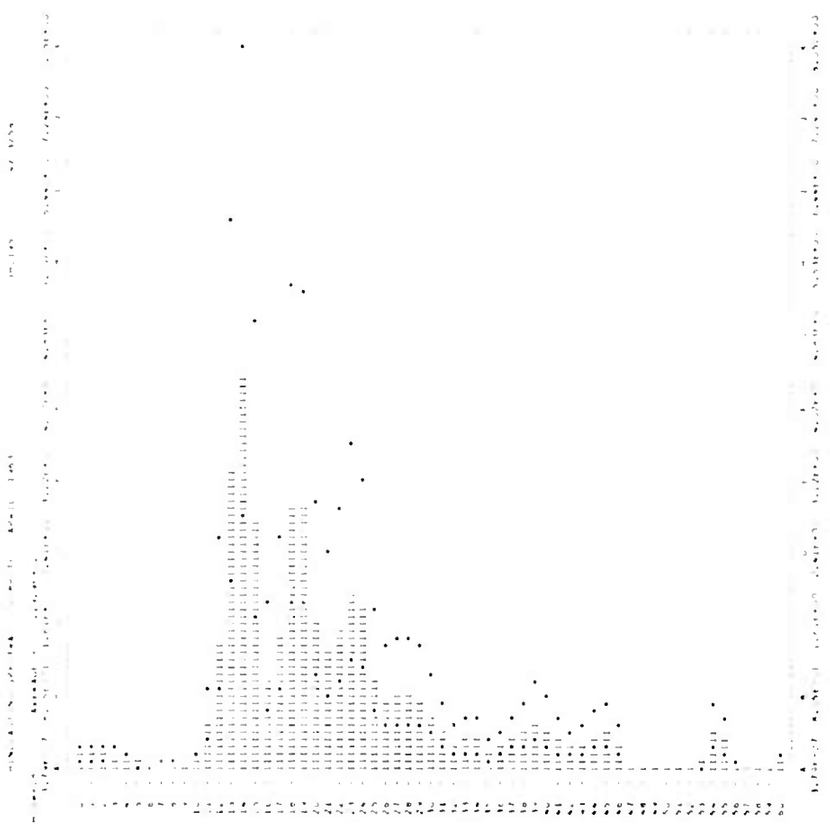
Record #	Date	Hour	Wind speed	Record #	Date	Hour	Wind speed
JHC 185	16/12/55	0	16	190		9	0
186		3	13	191		15	4
187		11	10	192		21	2
188		18	10	193	18/12/59	0	2
189	17/12/55	3	14				

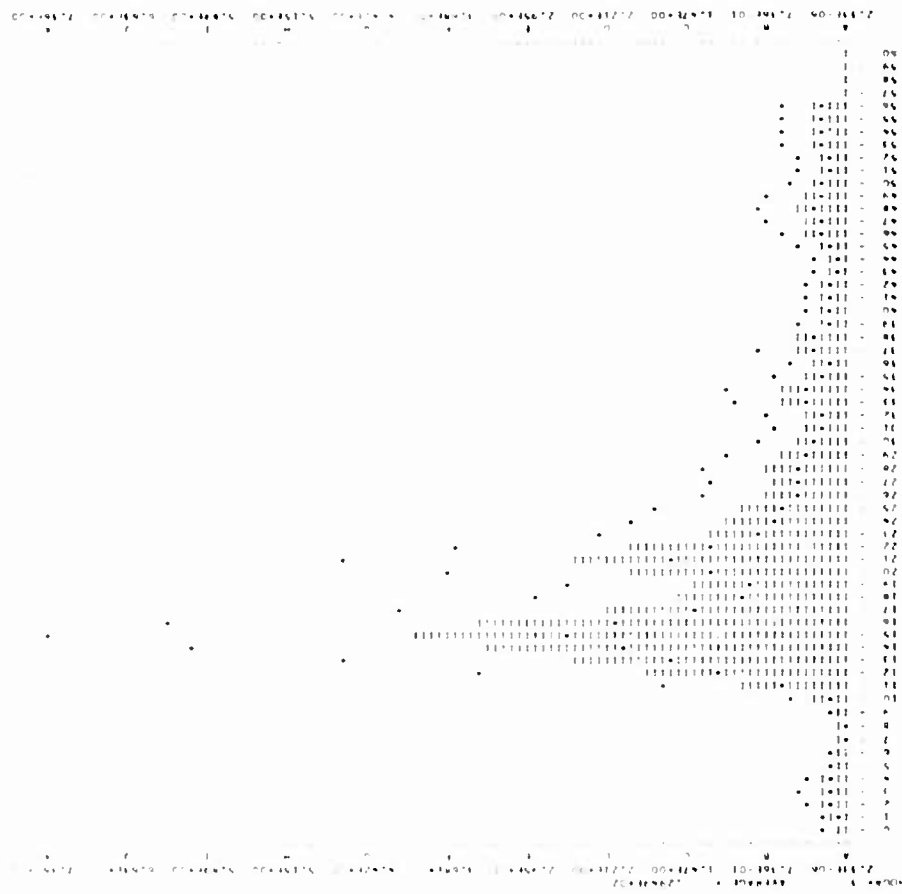
(Part III)

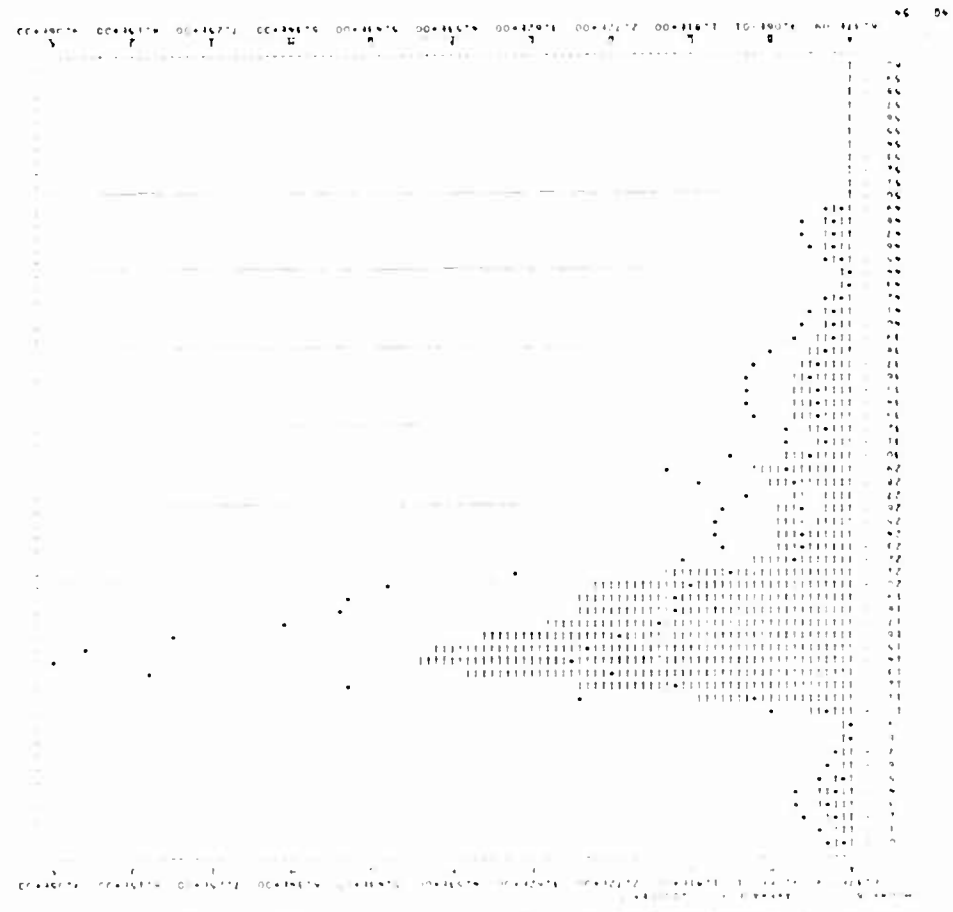
JHC 194	4/3/58	15	40	207		21	20
195		18	45	208	19/11/56	21	30
196	5/3/58	3	40	209	20/11/56	3	18
197		6	40	210		6	15
198		9	40	211		12	28
199		12	40	212		15	38
200		15	40	213		18	40
201		21	40	214		21	48
202	6/3/58	3	35	215	21/11/56	3	42
203		6	35	216		6	32
204		12	40	217		12	35
205		18	20	218		15	32
206	15/12/55	12	8	219		21	23

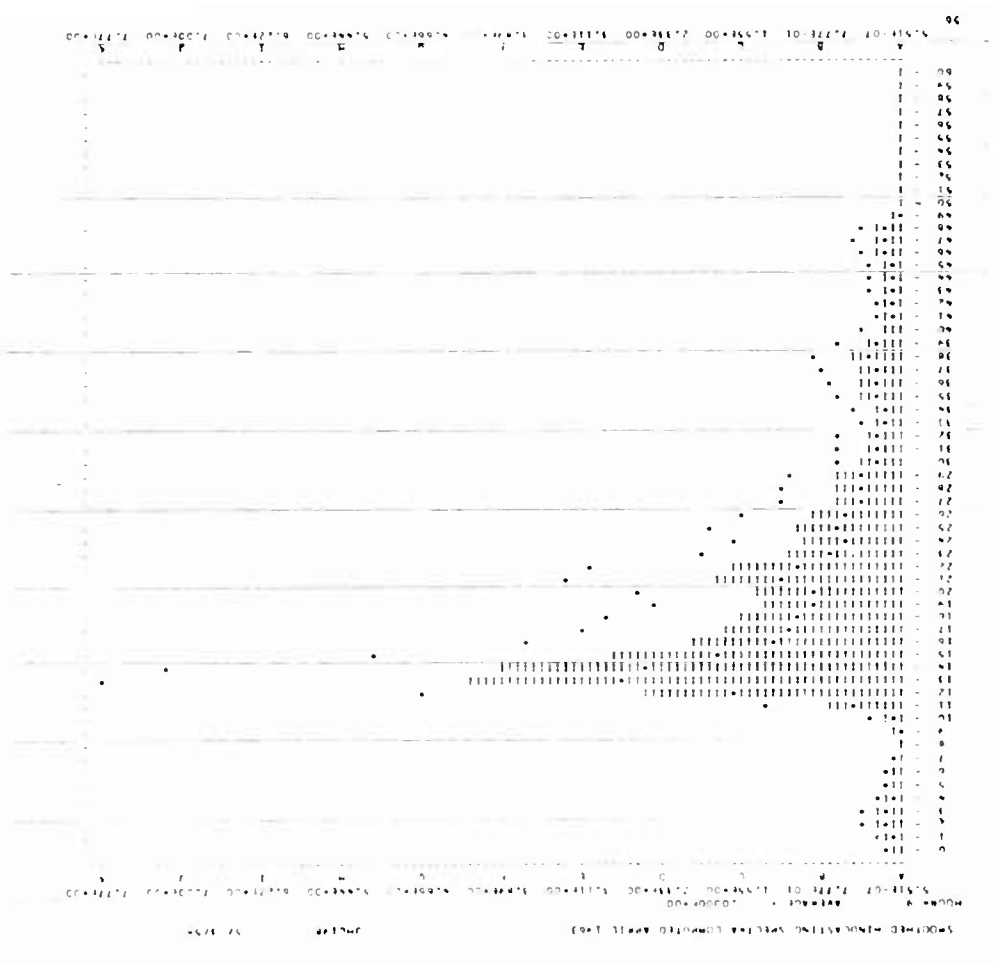
Record #		Date	Hour	Wind speed	Record #	Date	Hour	Wind speed
JHA	1	15/12/59	3	--	21		12	26
	2		6	--	22		15	36
	3		12	21	23		18	26
	4		18	25	24		21	23
	5	16/12/59	0	10	25	19/12/59	0	30
	6		6	4	26		3	35
	7		12	23	27		6	18
	8		18	32	28		9	18
	9	17/12/59	0	60	29		12	28
	10		3	61	30		15	25
	11		6	48	31		18	17
	12		9	48	32		21	14
	13		12	48	33	20/12/59	0	28
	14		15	48	34		6	36
	15		18	48	35		12	28
	16		21	41	36		18	16
	17	18/12/59	0	40	37	21/12/59	0	28
	18		3	25	38		6	27
	19		6	20	39		12	7
	20		9	9	40		17	23

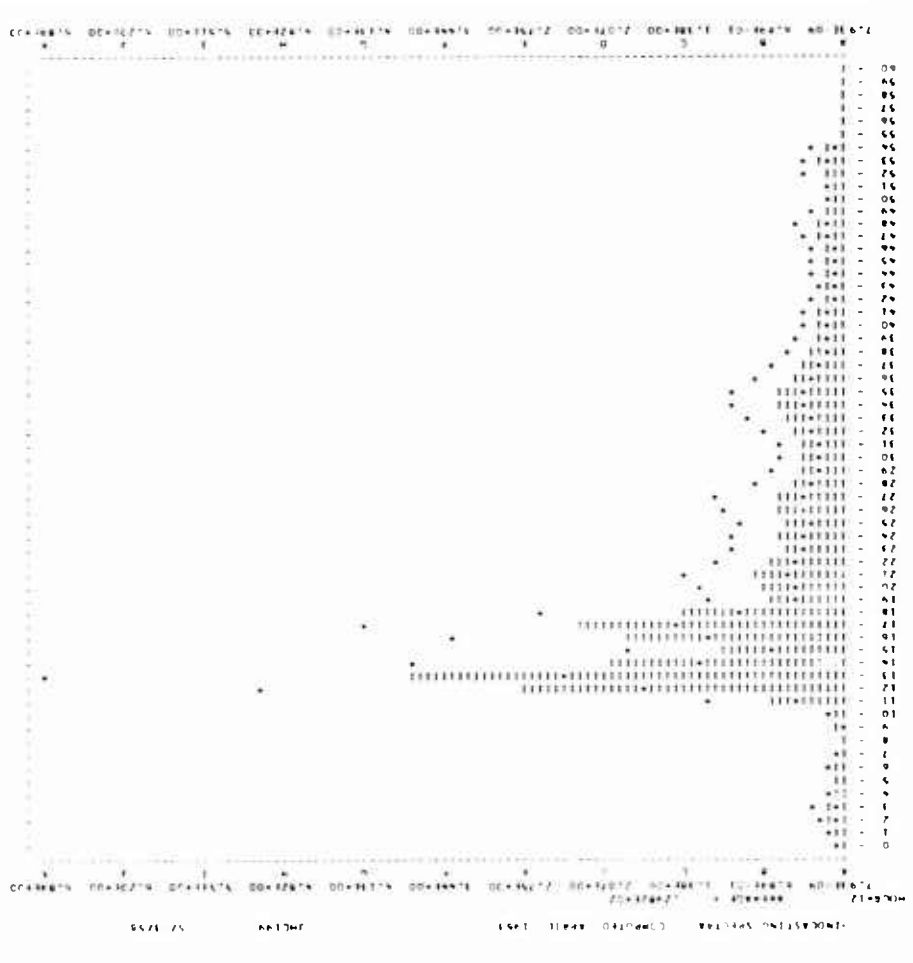


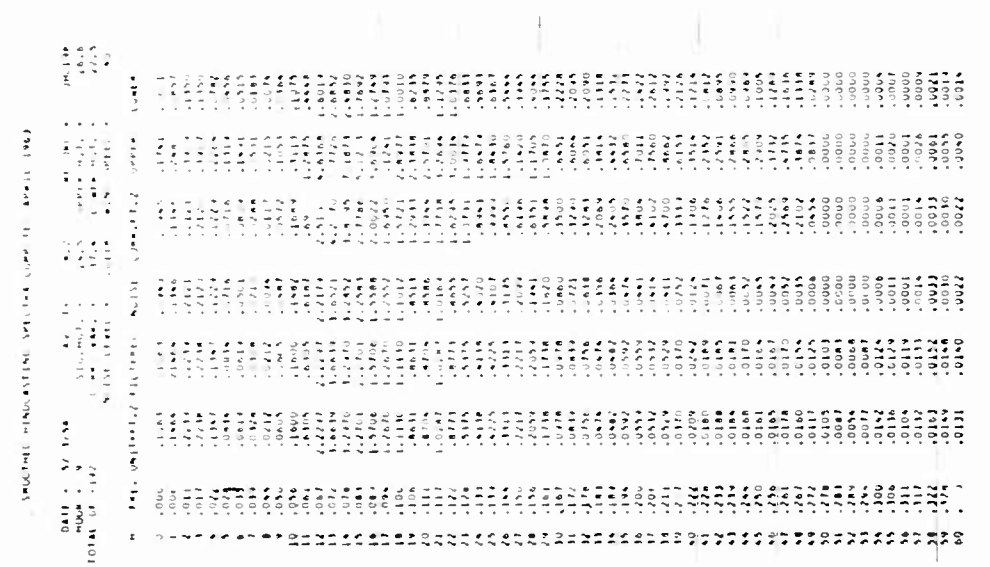


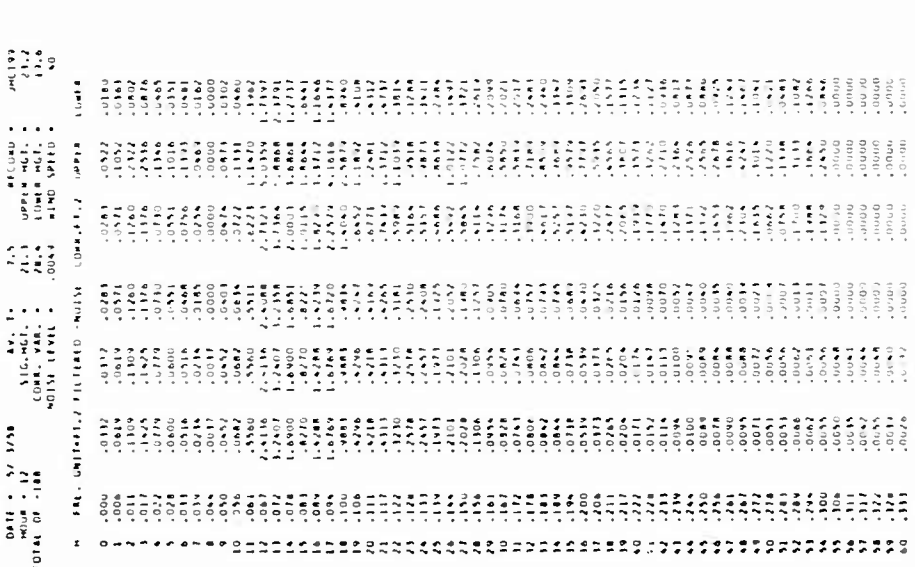


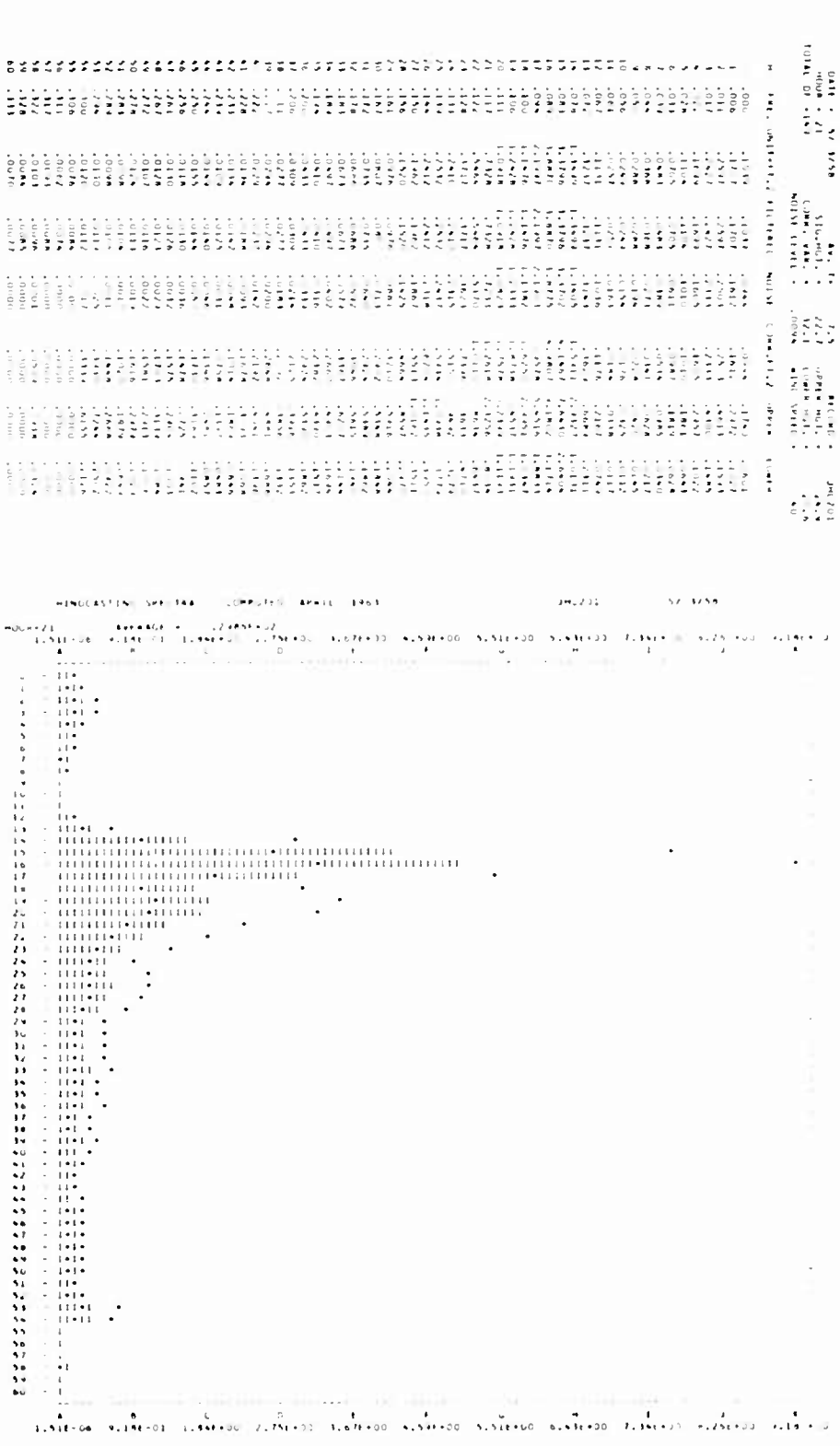


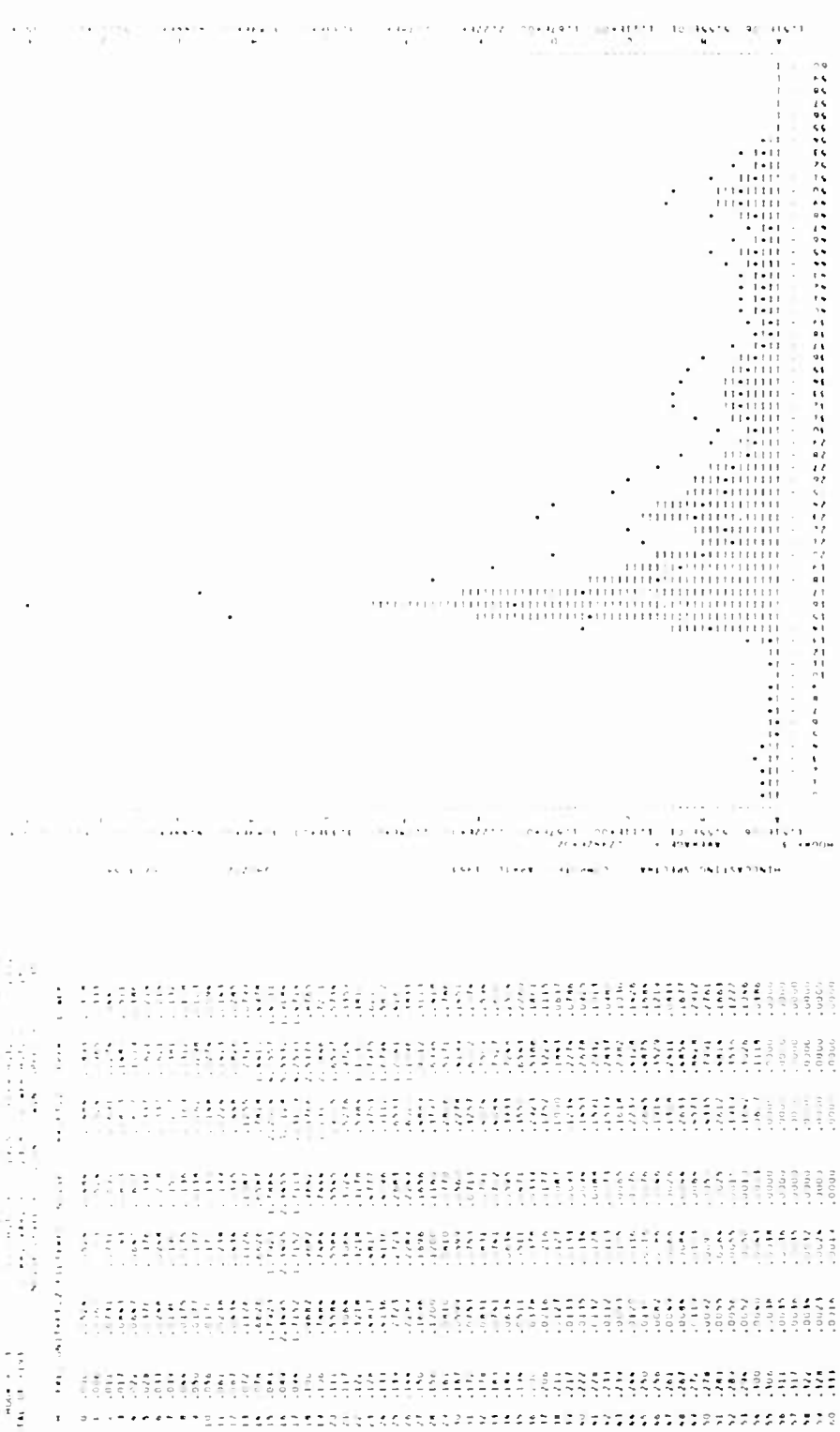


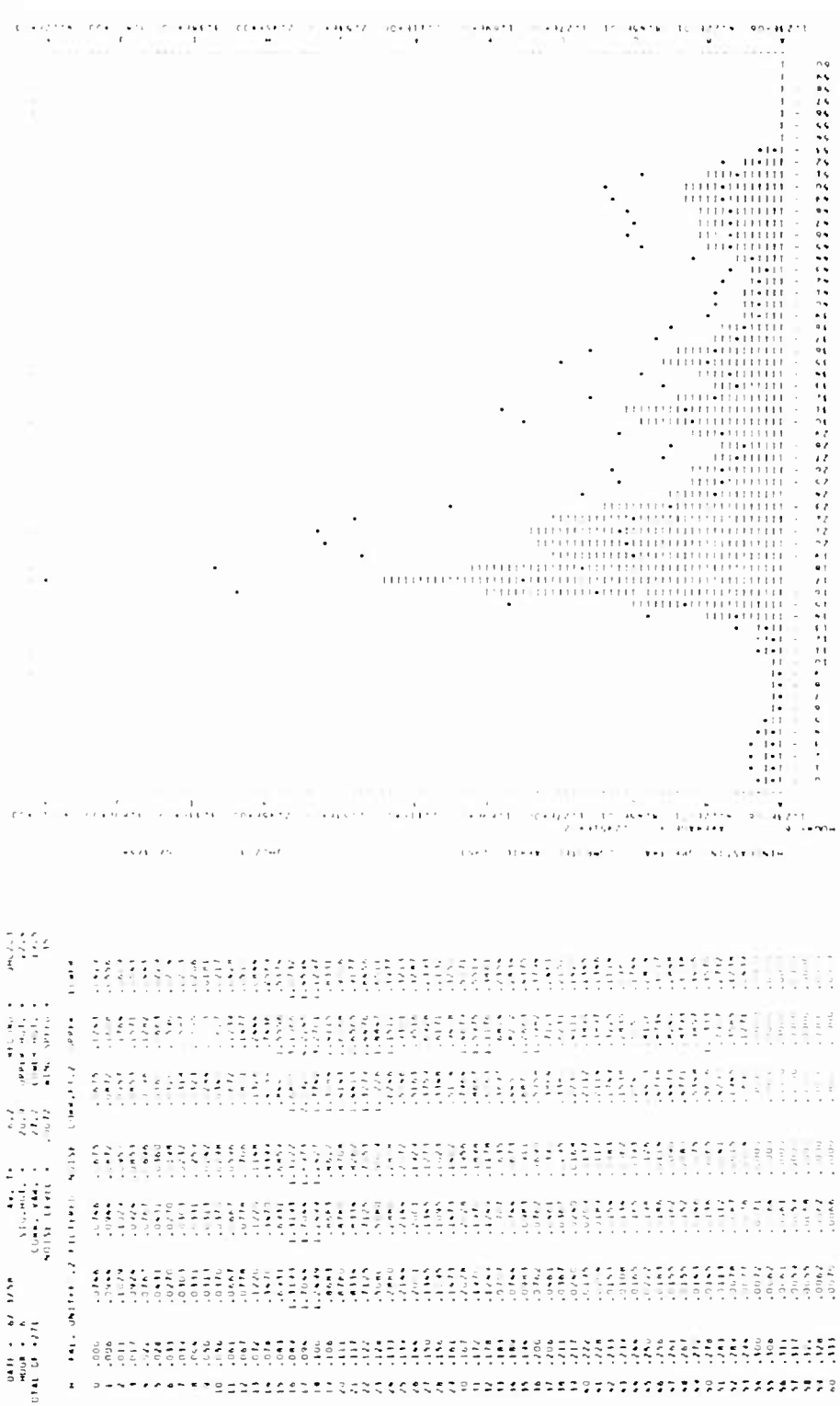


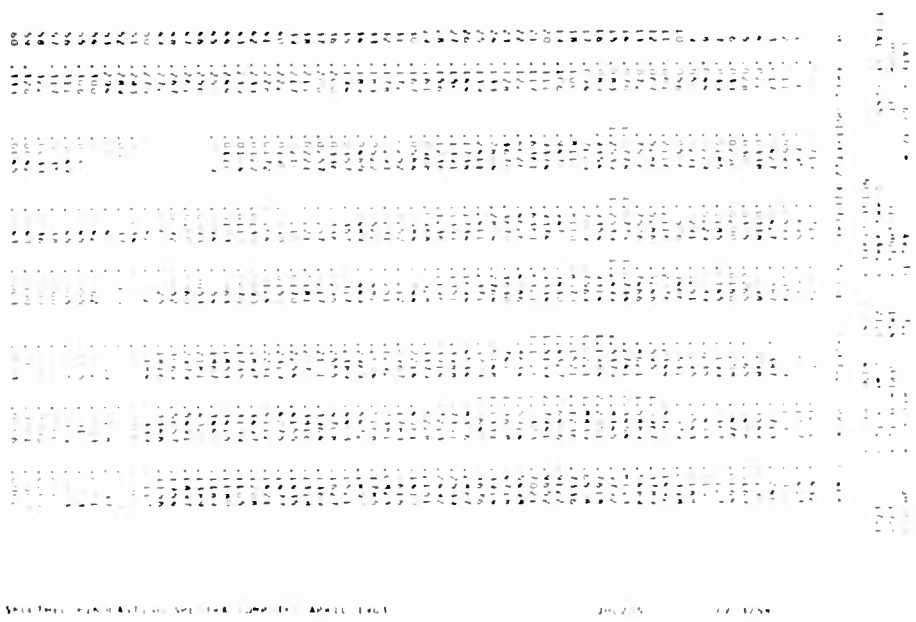


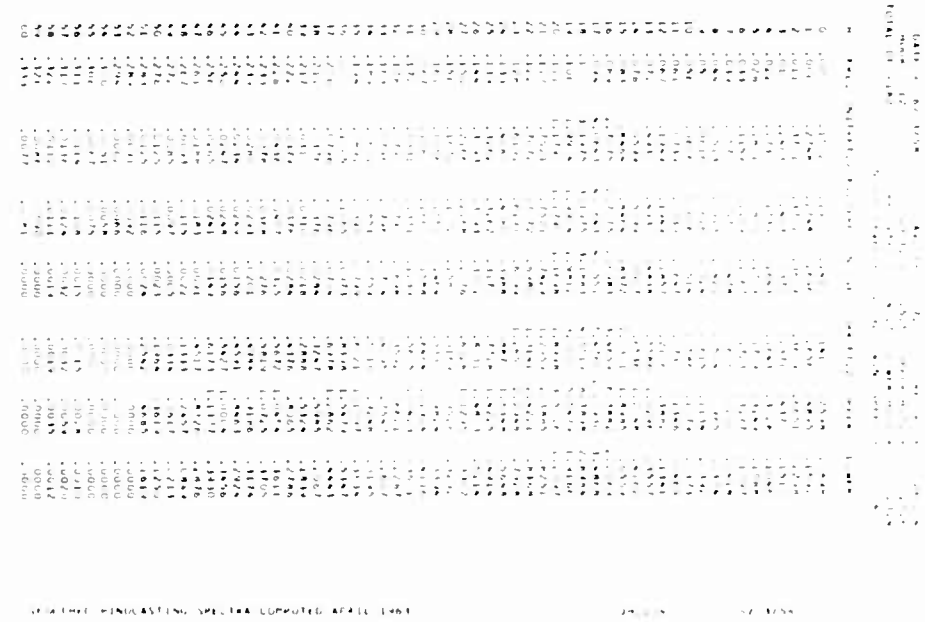


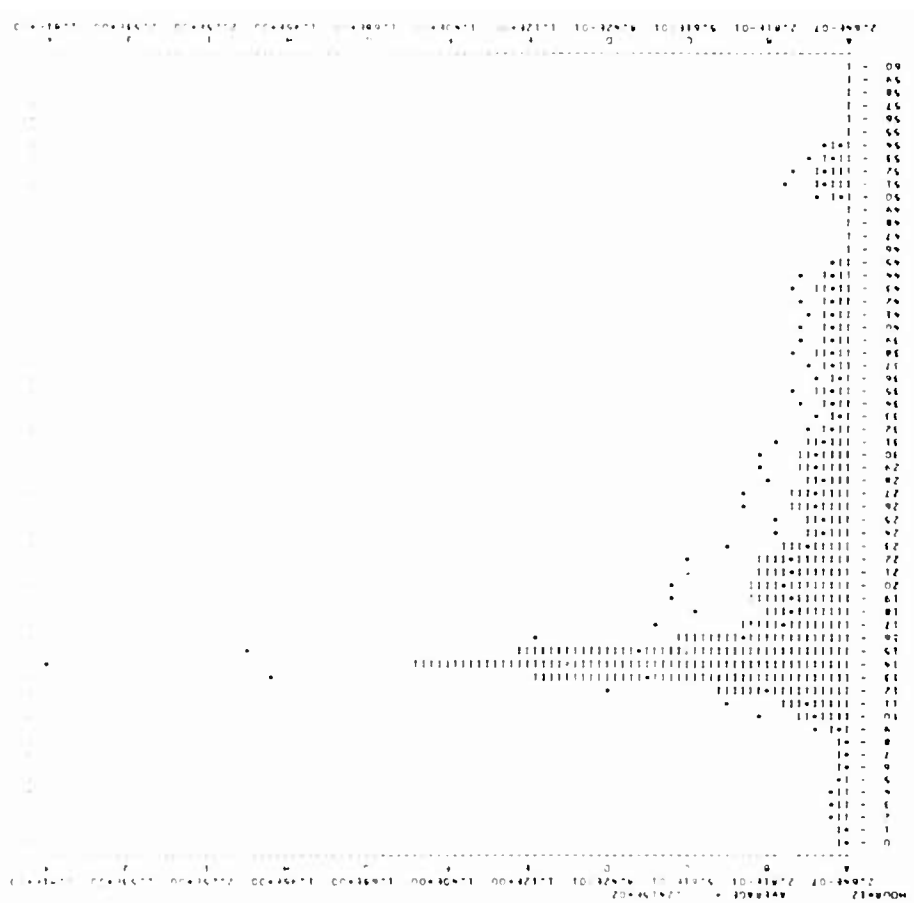


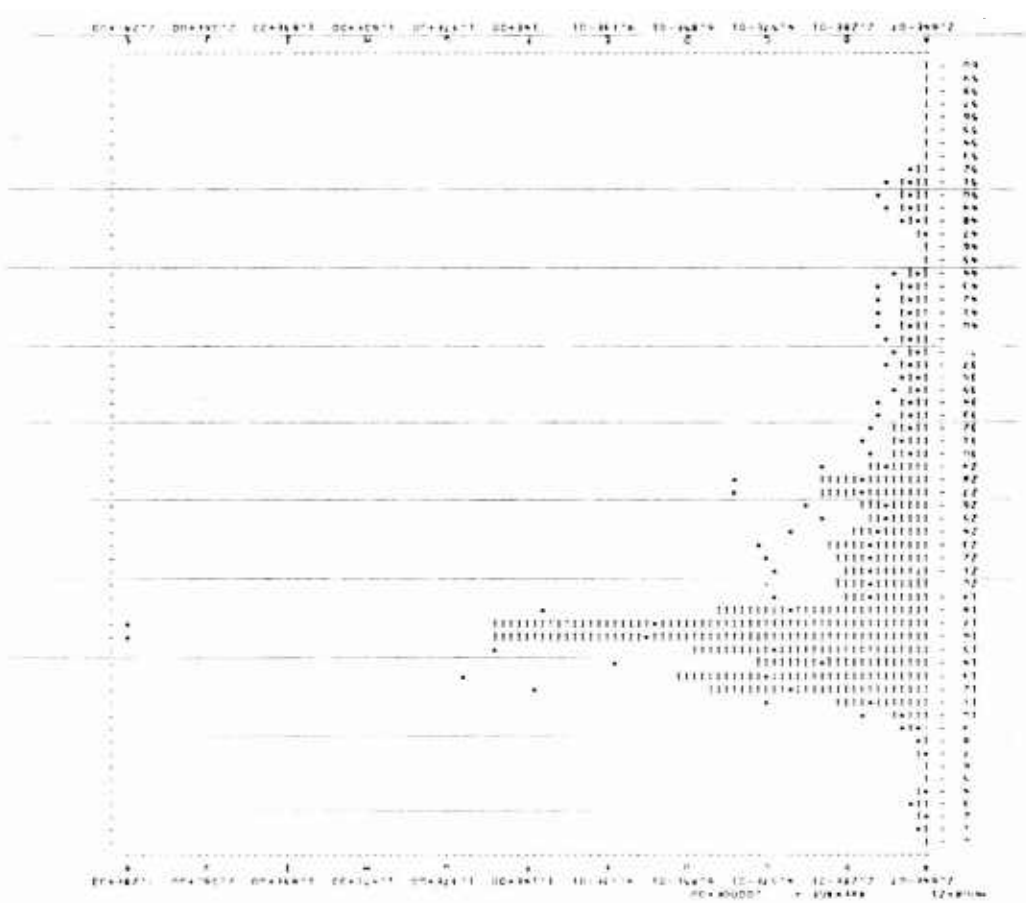


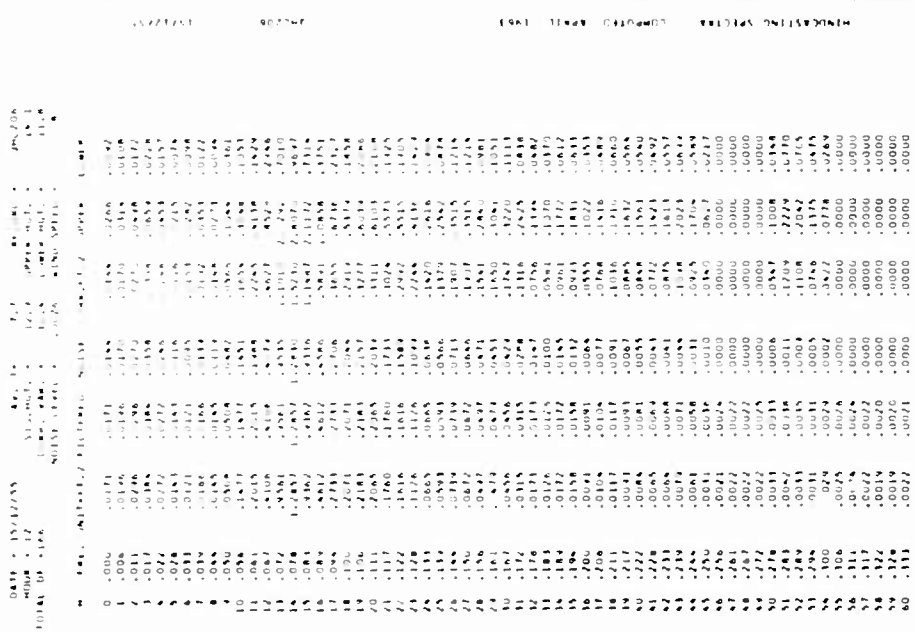


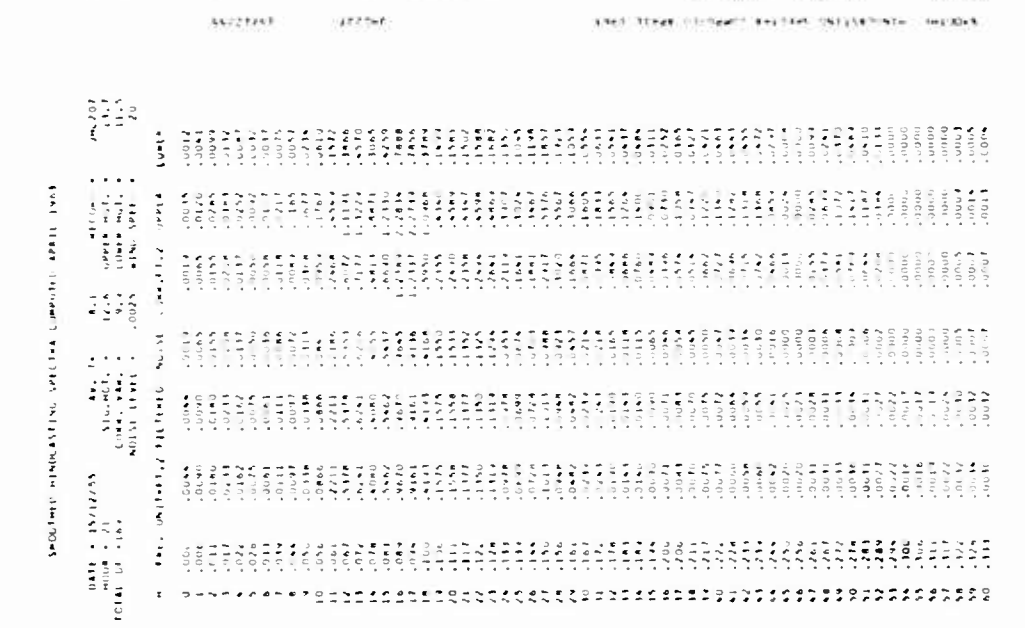


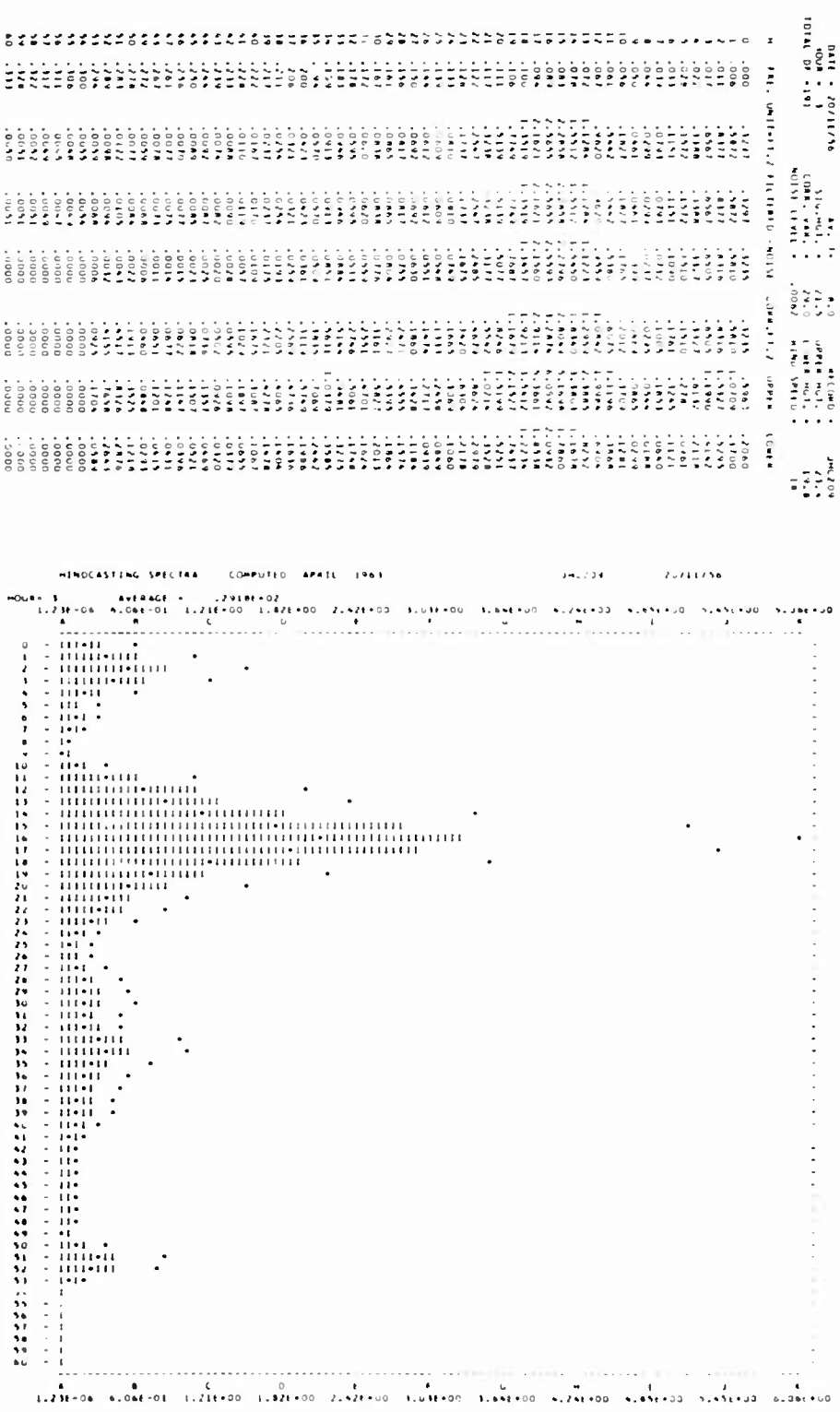


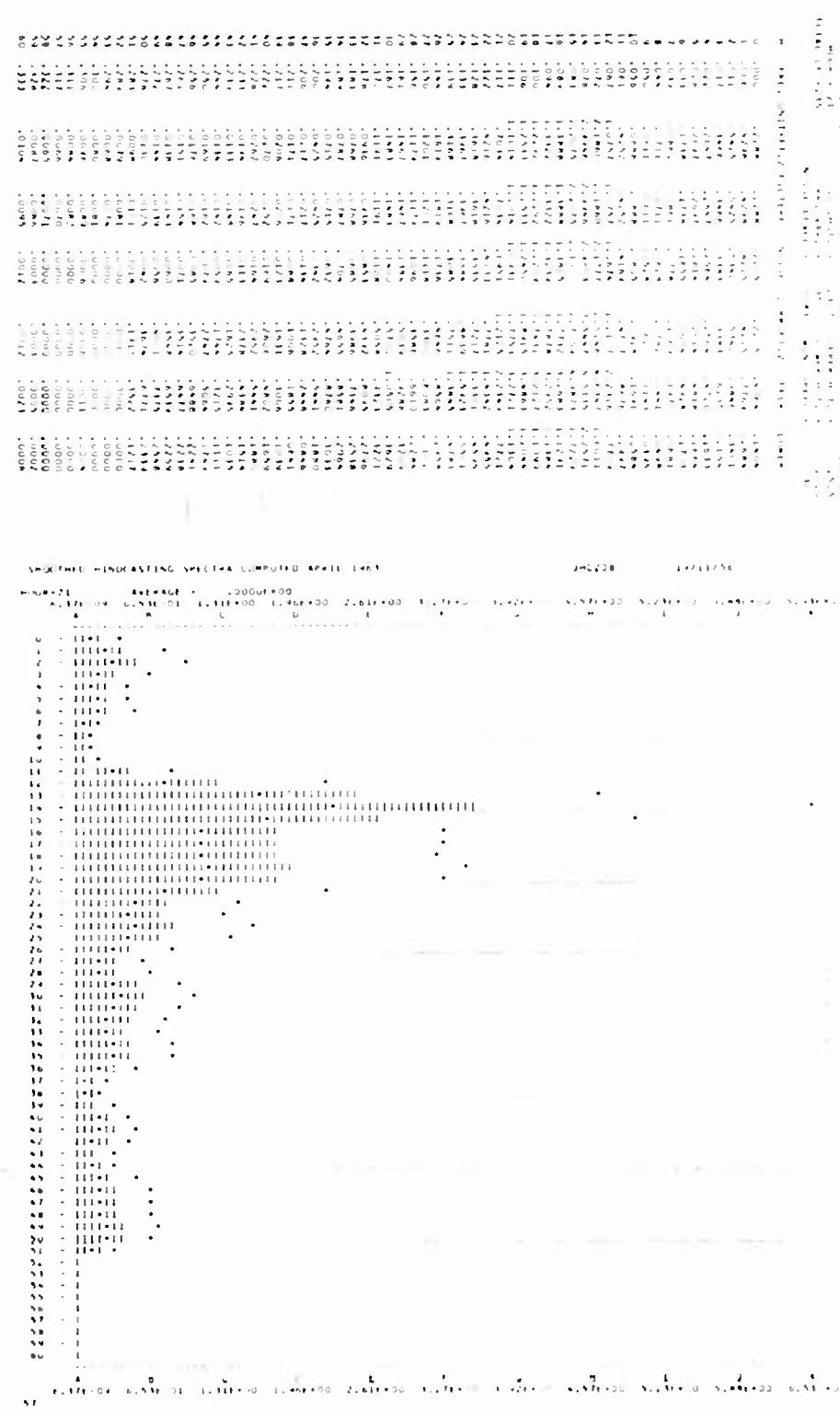


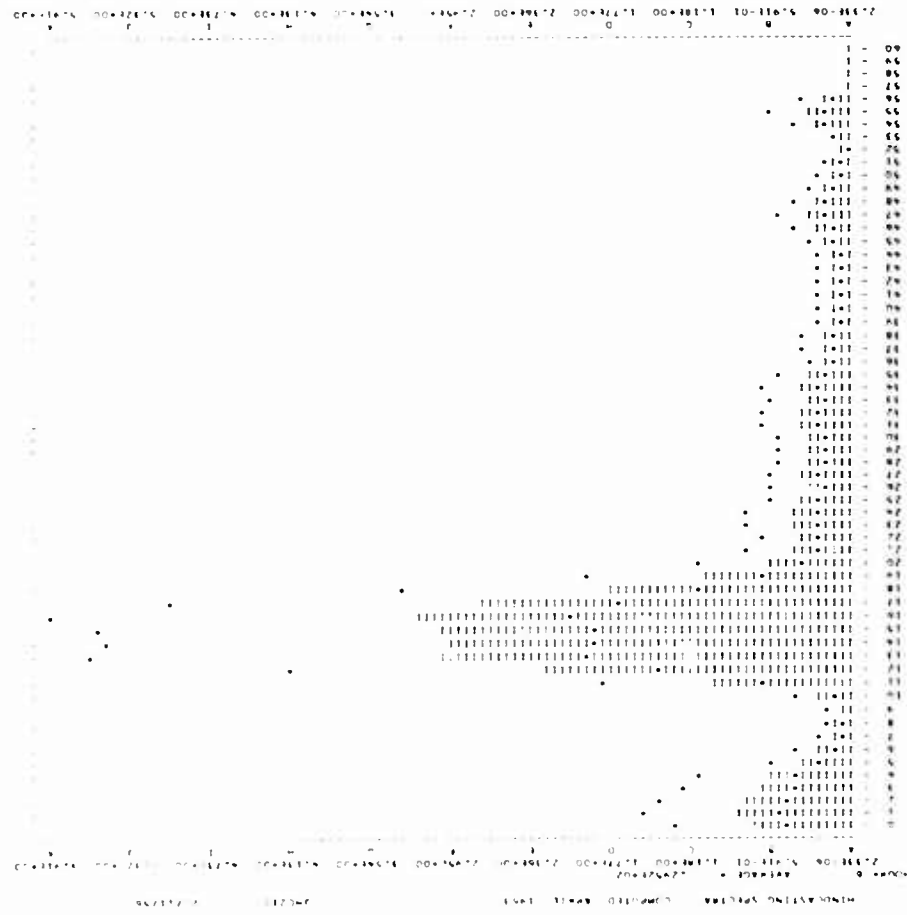


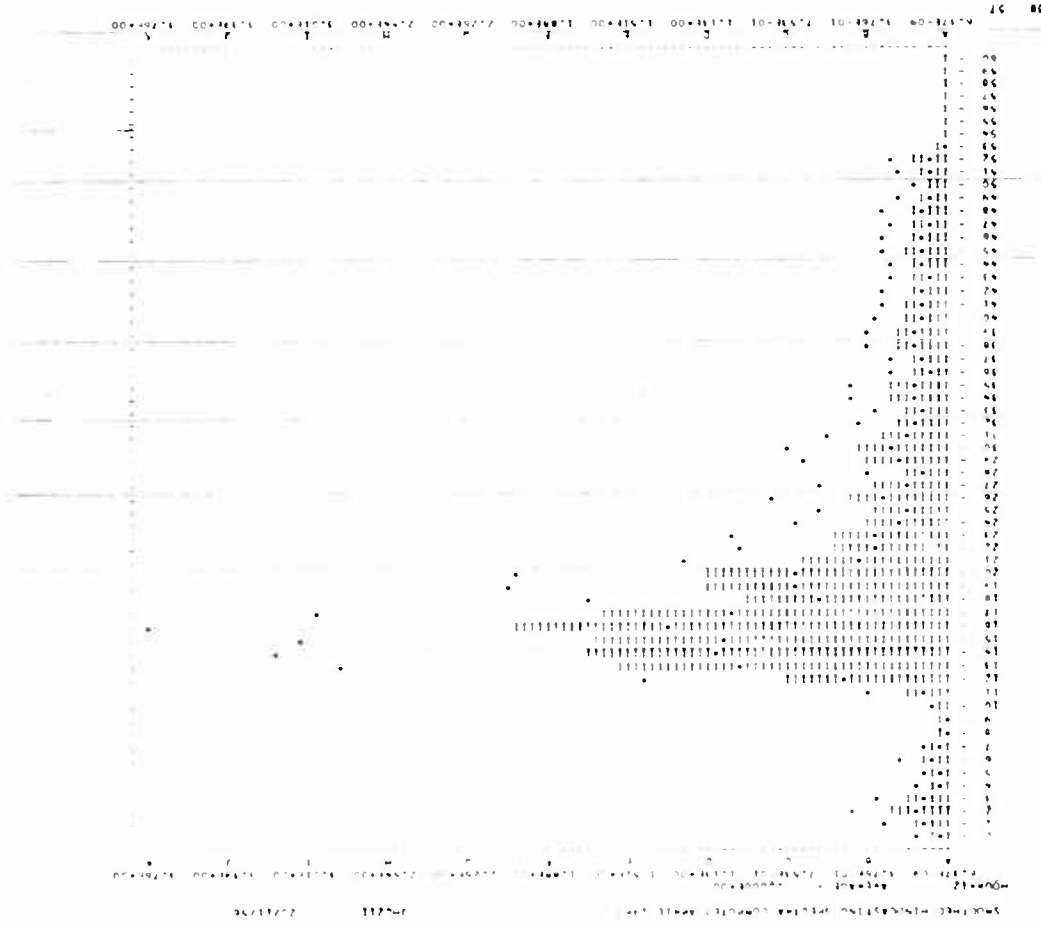


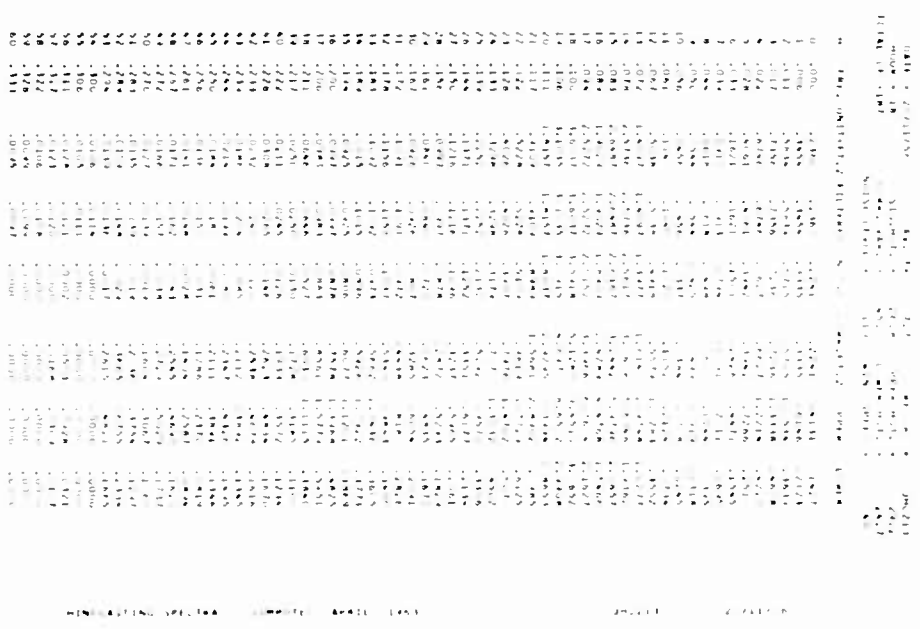


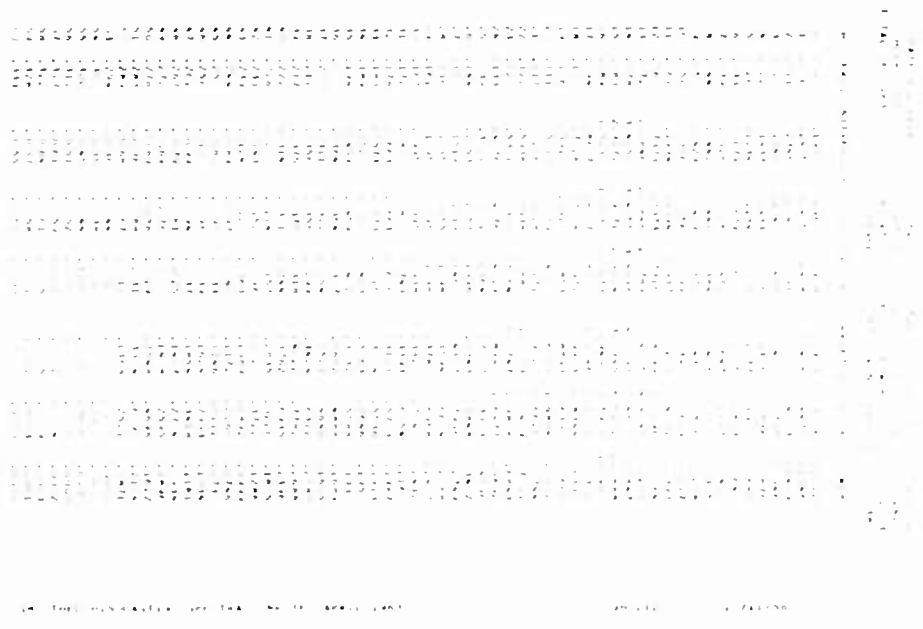

HINDCASTING SPECTRA COMPUTED APRIL 1961
HOUR= 3 AVERAGE = .2918E+02
1.23E+00 6.06E-01 1.21E+00 1.82E+00 2.42E+00 3.03E+00 3.66E+00 4.25E+00 4.85E+00 5.45E+00 6.06E+00
A B C D E F G H I J K

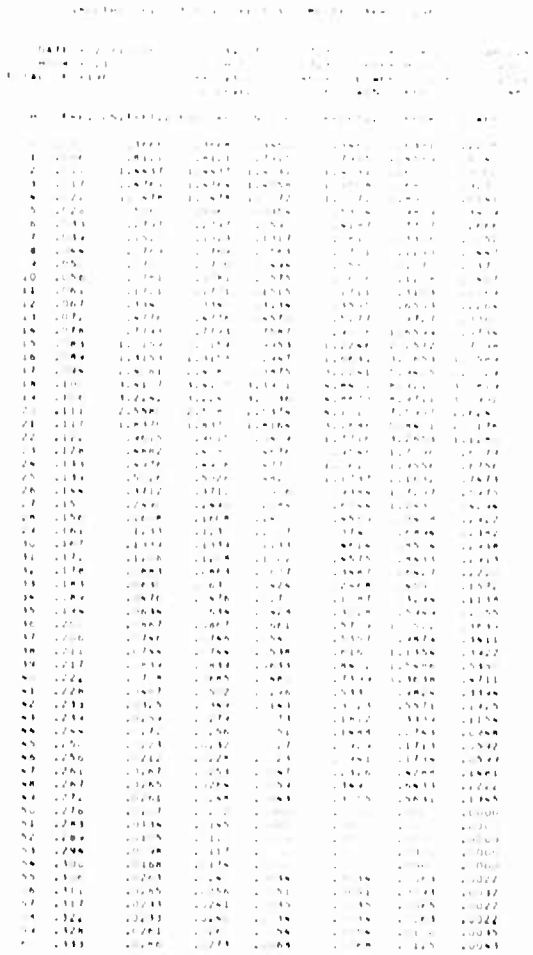

SMOOTHED HINDCASTING SPECTRA COMPUTED APRIL 1961
HOUR=21 AVERAGE = .3000E+00
A B C D E F G H I J K

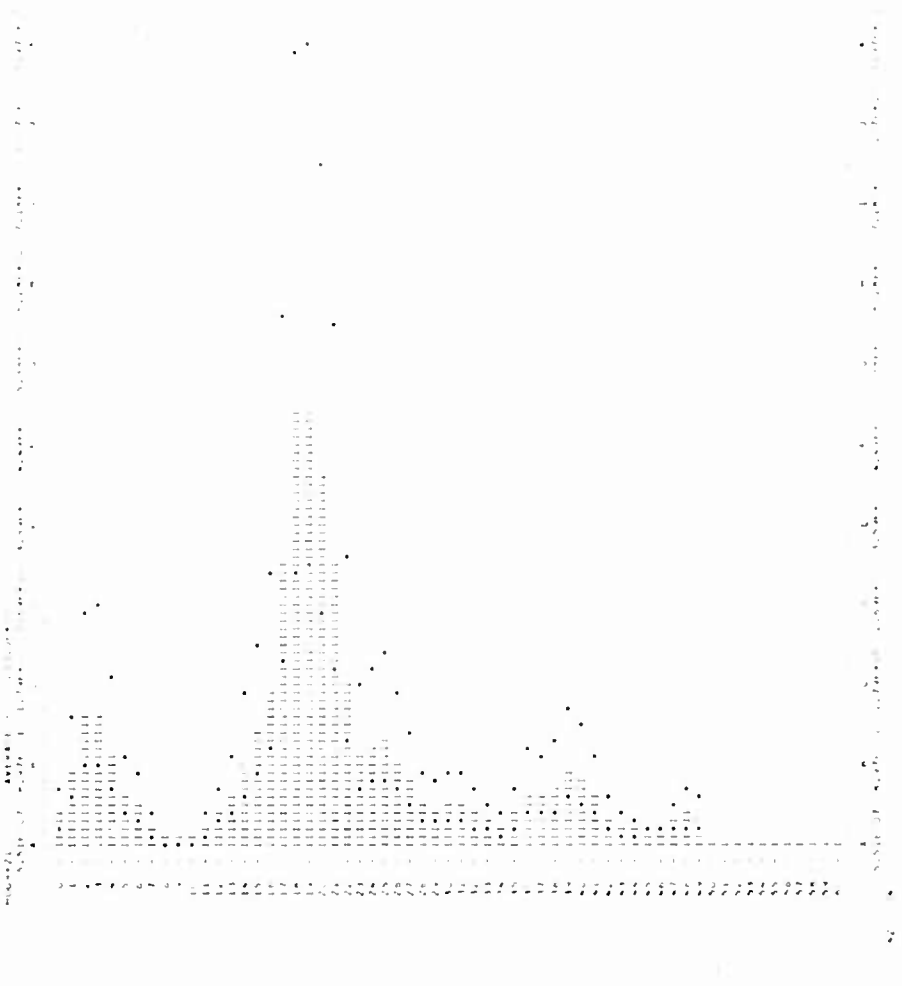


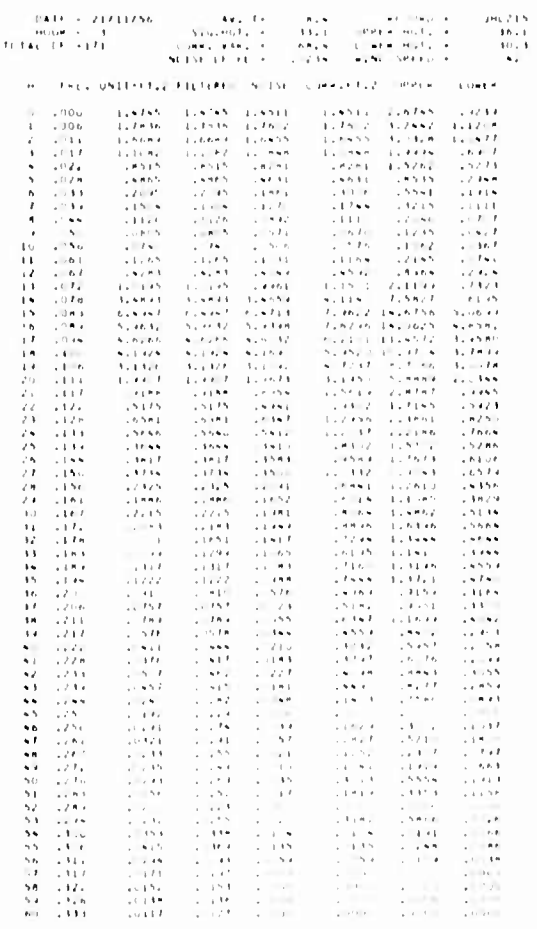


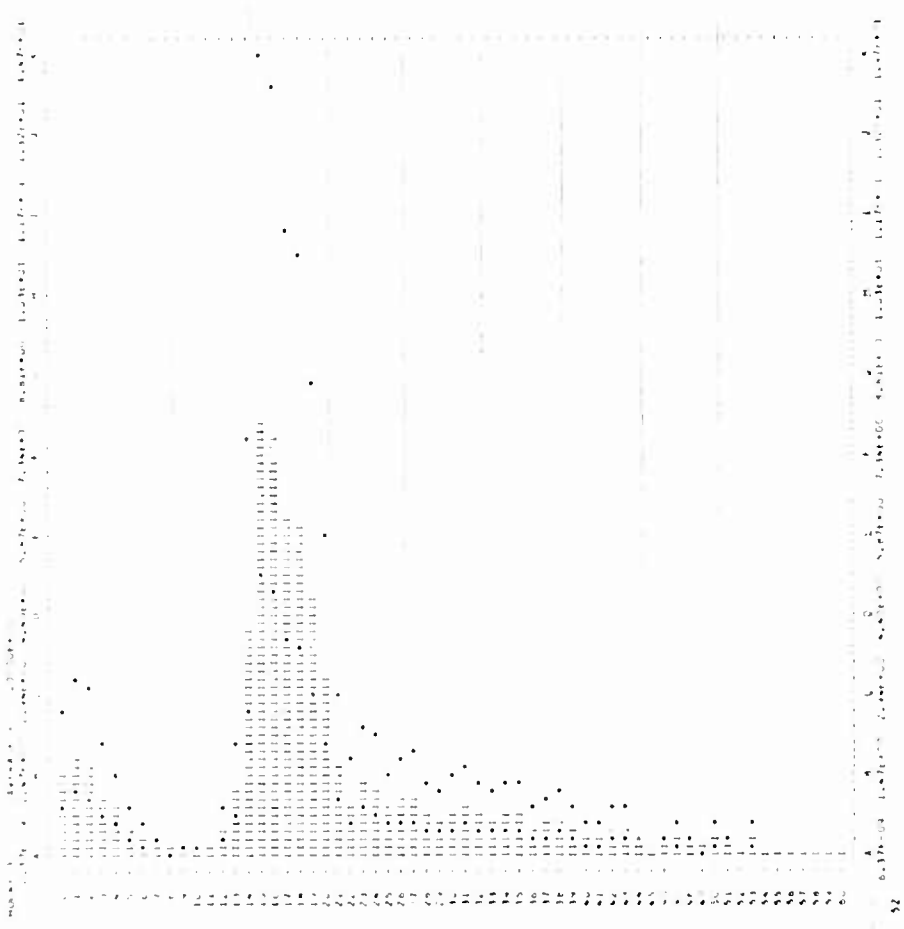


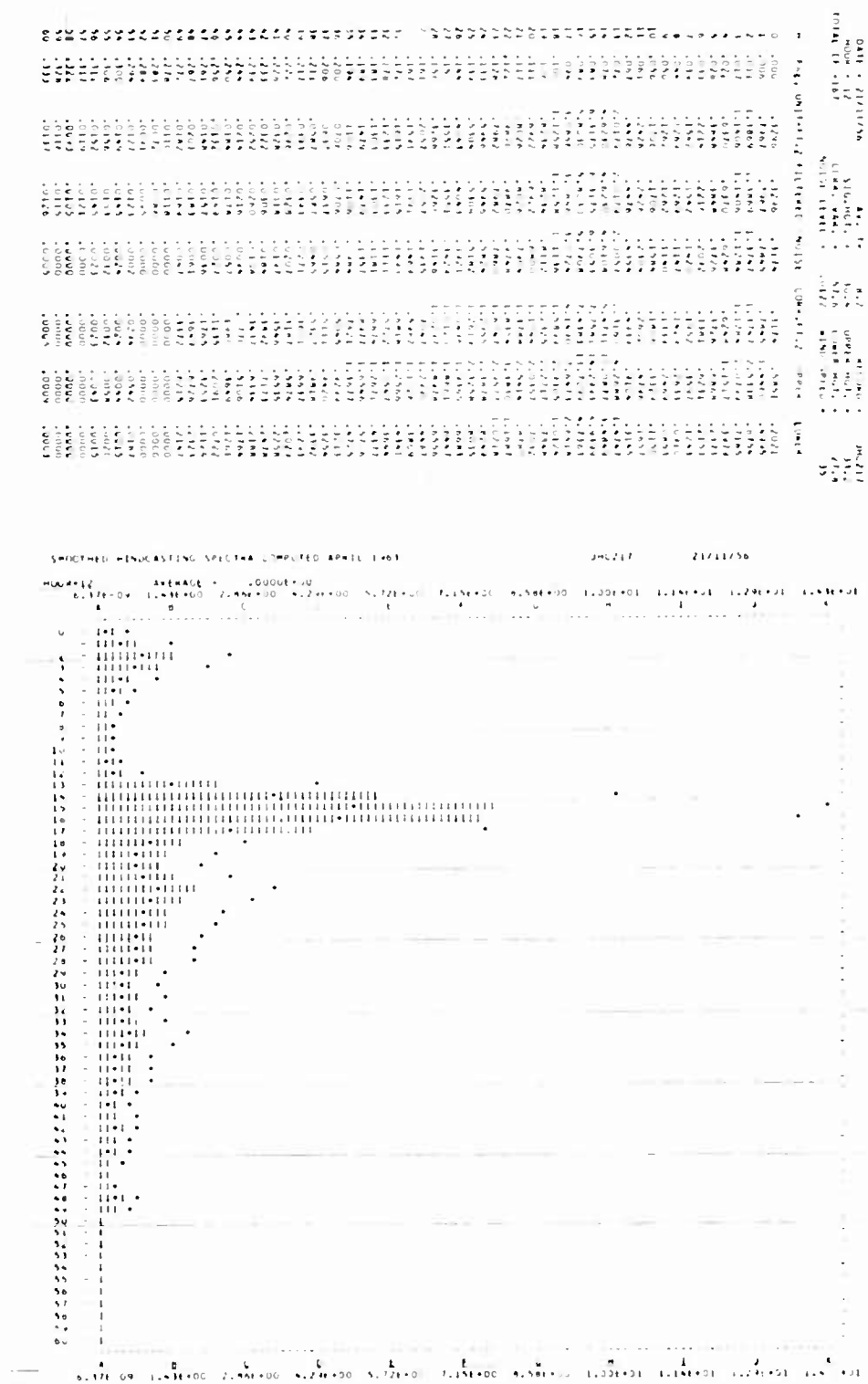


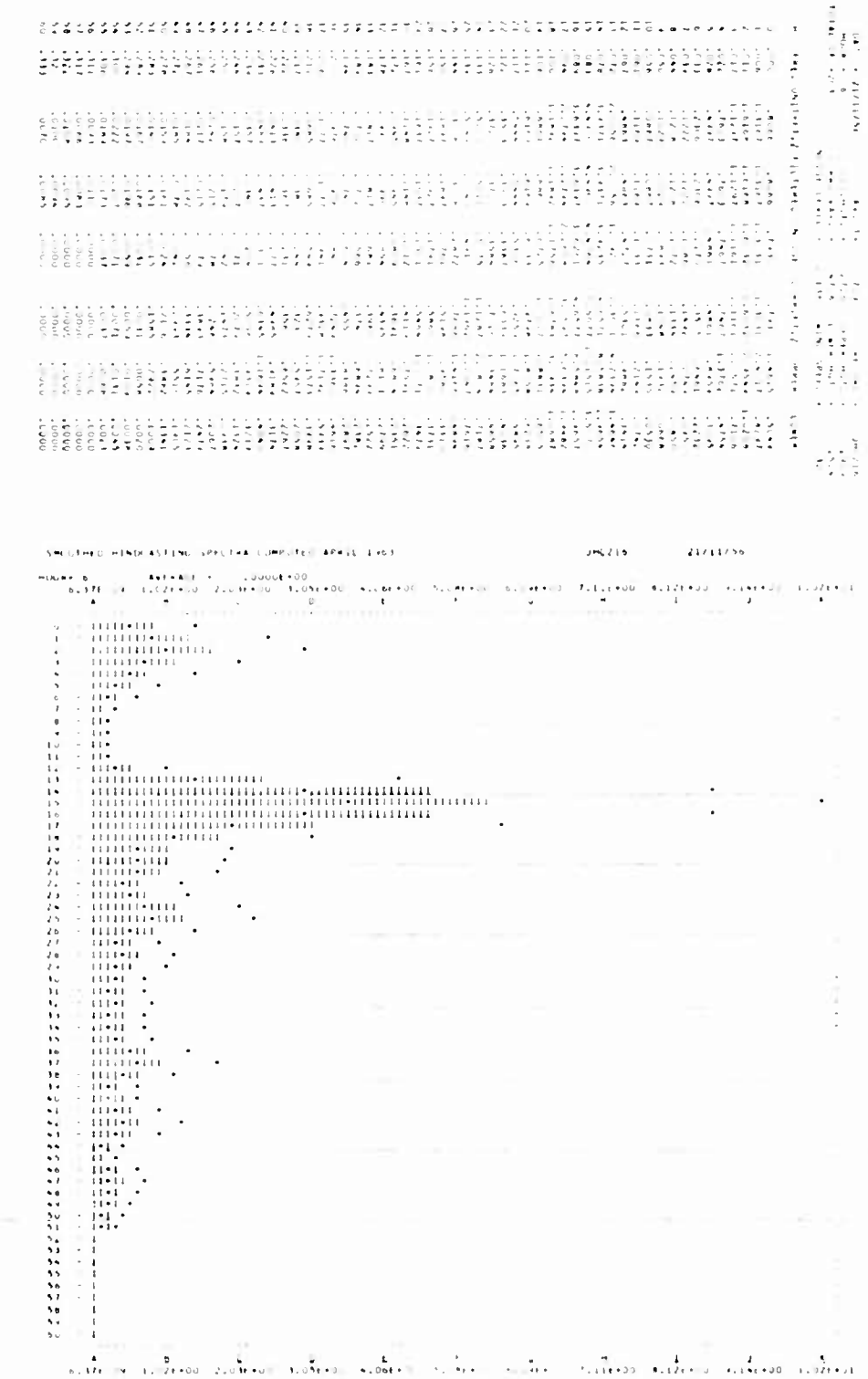


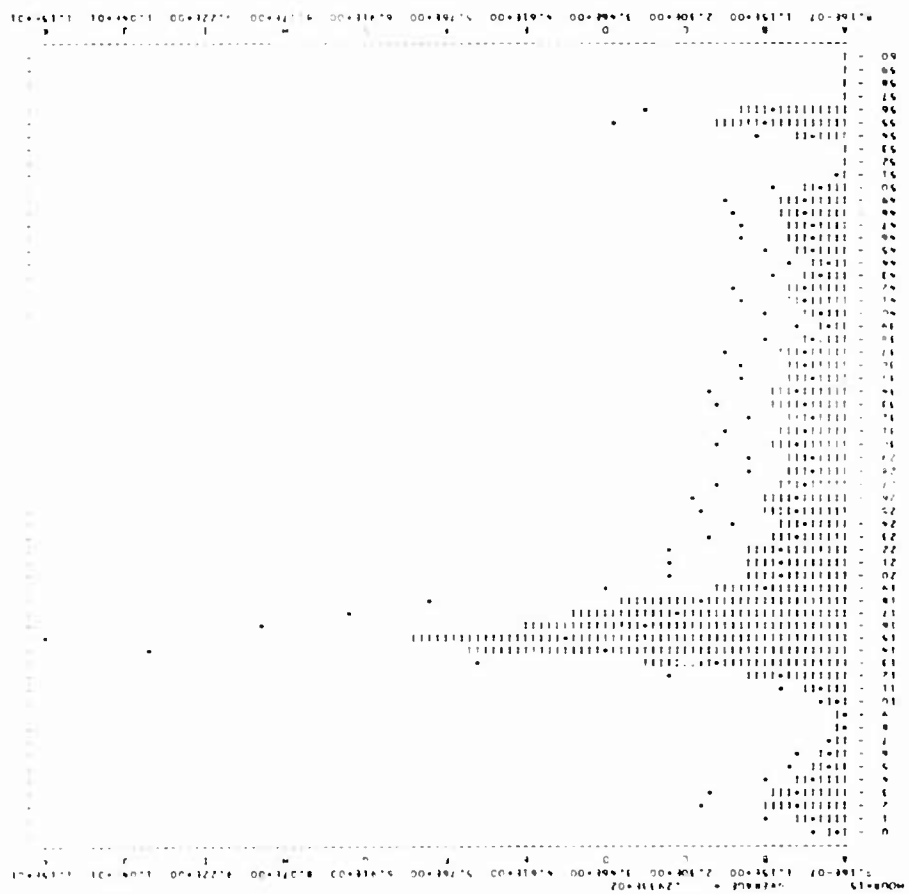


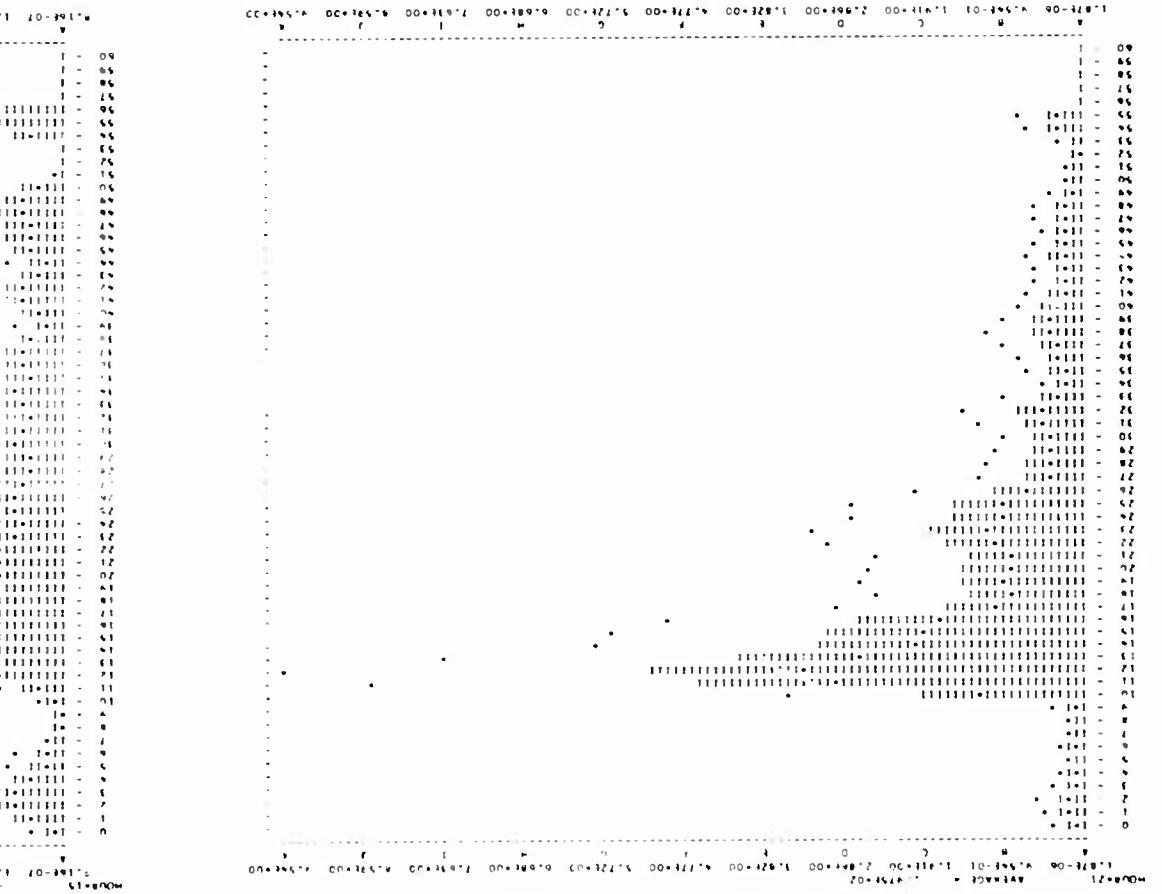





SMOOTHED HINDCASTING SPECTRA COMPUTED APRIL 1983
JHS217
21/11/56

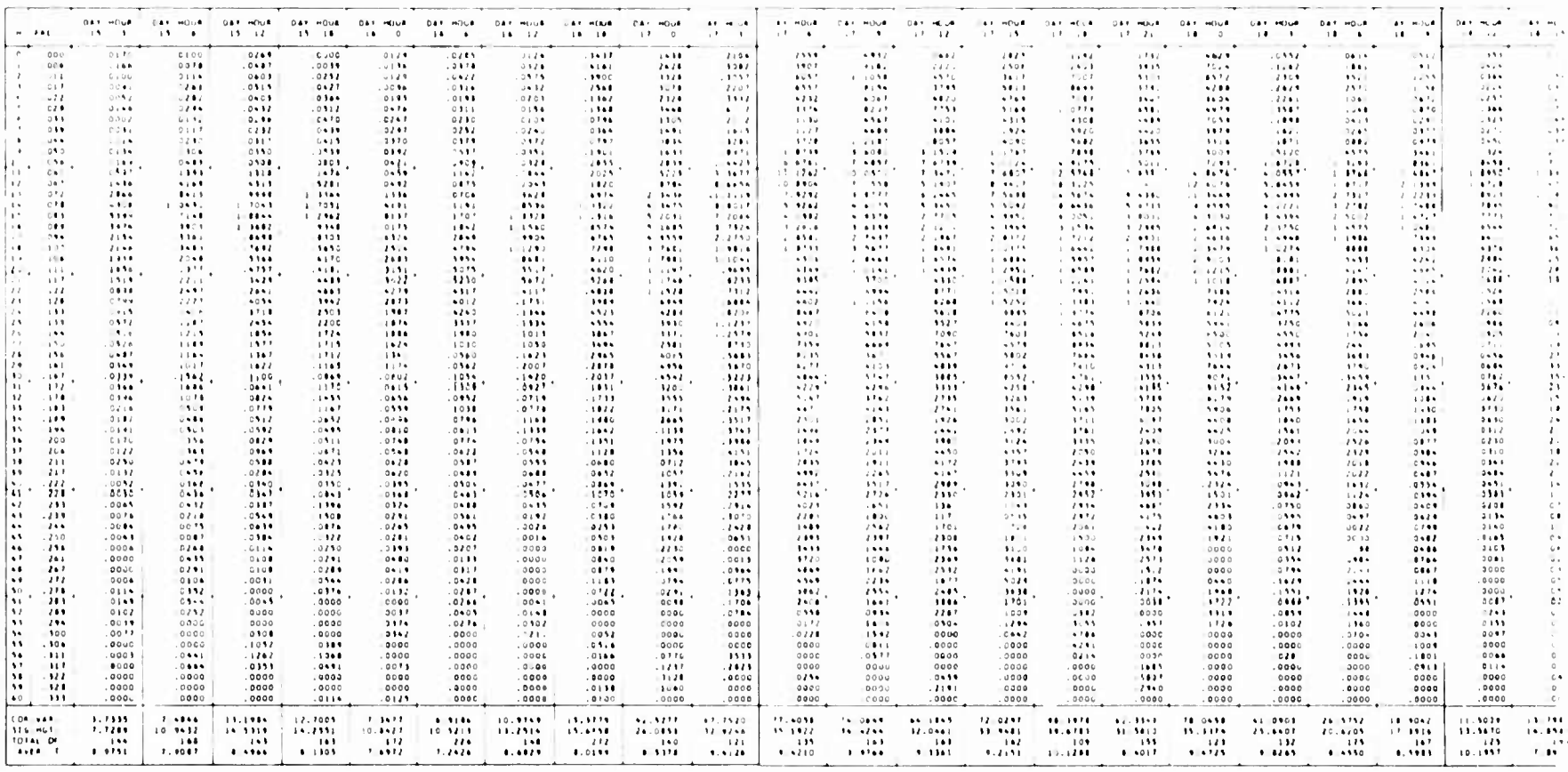

SMOOTHED HINDCASTING SPECTRA COMPUTED APRIL 1983
JHS219
21/11/56





Data for High Wave Conditions Observed by the OWS "W

Wave Spectra Computed from Wave Records Obtained by



A

served by the OWS "Weather Reporter" in December 1959

Wave Records Obtained by the OWS "Weather Reporter"

DAY HOUR 10 6	DAY HOUR 10 9	DAY HOUR 10 12	DAY HOUR 10 15	DAY HOUR 10 18	DAY HOUR 10 21	DAY HOUR 11 0	DAY HOUR 11 3	DAY HOUR 11 6	DAY HOUR 11 9	DAY HOUR 11 12	DAY HOUR 11 15	DAY HOUR 11 18	DAY HOUR 11 21	DAY HOUR 12 0	DAY HOUR 12 3	DAY HOUR 12 6	DAY HOUR 12 9	DAY HOUR 12 12	DAY HOUR 12 15	DAY HOUR 12 18	N	FREQ.
.0616	.0512	.1351	.0031	.0435	.0103	.0447	.0079	.0101	.0075	.0366	.0127	.0360	.0151	.0182	.0256	.0310	.0275	.0360	.0332	.0110	.0131	1	000
.1861	.0911	.0424	.0187	.0761	.0536	.0751	.0419	.0552	.0292	.0575	.0245	.0360	.0191	.0291	.0240	.0366	.0301	.0366	.1115	.0347	.0231	2	000
.3521	.1755	.0366	.0351	.1001	.0691	.0915	.1142	.0719	.0518	.0960	.0351	.0366	.0447	.0474	.0521	.0183	.0183	.0183	.0965	.2174	.1009	3	011
.2571	.1159	.0329	.0366	.0366	.0548	.0548	.1234	.0896	.0611	.0731	.0366	.0366	.0366	.0548	.0402	.0548	.0402	.0731	.0285	.0822	.1193	4	017
.1061	.0612	.0329	.0146	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	5	022
.1048	.0870	.0366	.0475	.1001	.0475	.0548	.0731	.1035	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	6	028
.0615	.0290	.0329	.0548	.0416	.0278	.0509	.0584	.0613	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	7	033
.0265	.0577	.0731	.0387	.0628	.0180	.0618	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	8	039
.0882	.0979	.0548	.0182	.0867	.0172	.0380	.0421	.0695	.0278	.0028	.0329	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	.0548	9	044
.4575	.3661	.1326	.2022	.1768	.0666	.1233	.1329	.1195	.0686	.0086	.0232	.0183	.0183	.0183	.0183	.0183	.0183	.0183	.0183	.0183	.0183	10	050
1.3193	.8361	.4548	.3048	.1504	.4008	.3766	.3887	.4050	.3915	.0432	.0914	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	.0731	11	056
1.8768	1.4867	1.3855	1.3468	1.9910	1.4080	.8886	.9667	.7776	1.0261	.1298	.2194	.1041	.1637	.1098	.2068	.1041	.5127	1.6933	2.4164	2.8219	1.1369	12	061
1.8717	2.1309	1.6978	1.4765	2.2488	2.2857	1.6990	.9187	.7057	1.1594	.3816	.3474	.4664	.5305	1.5715	2.5788	4.4367	4.8784	.5287	12	067
2.7517	2.2253	.9821	1.1803	1.5586	1.6004	1.2366	.8360	.5868	.8781	.8857	.8111	.2564	2.5155	2.3210	2.8210	.9762	2.5636	1.9706	1.0088	.5512	.7507	13	072
3.2782	1.7408	.7845	.9058	.2760	.6870	.8124	.6691	.6185	.4536	1.2531	1.1962	2.8517	1.3931	2.3918	1.1090	2.6818	2.6967	1.5075	2.2867	2.9035	1.4576	14	078
2.5012	1.6727	.9715	.7065	.9678	.9893	.3097	.6548	.8658	.4669	1.6831	1.4317	2.2958	1.2454	1.9521	1.3336	1.8282	1.9531	1.4180	1.4128	2.8930	1.6483	15	083
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.8868	.6300	.4378	.3677	.4379	.5843	1.0838	1.2818	1.2705	.5755	.9686	.6743	.9250	.6877	.5799	.7855	1.0570	.6092	.8770	1.2439	1.0702	.6810	18	100
.5433	.4242	.2886	.3472	.3570	.4961	.4851	1.2380	1.0335	.5796	.8267	.4	.4408	.4067	.5227	.5285	.9157	.6598	.6015	1.5217	.7253	.4736	19	106
.4367	.4865	.2264	.2833	.3529	.3810	.4064	.9215	1.0042	.6272	.5780	.3716	.2853	.2851	.3179	.3801	.4468	.4490	.2608	.2772	.3993	.3009	20	111
.2855	.3014	.1688	.1958	.4764	1.0129	.3014	.3540	.4258	.5883	.2318	.1815	.1449	.1936	.2216	.4137	.3233	.2858	.5936	.2831	.2269	.2197	21	117
.2890	.2986	.1526	.1026	.4561	.7512	.3618	.4769	.4265	.5619	.5735	.3	.1374	.1788	.2125	.3981	.4188	.2538	.2672	.3795	.5185	.2464	22	122
.1681	.2	.1568	.1044	.1707	.4531	.2521	.2861	.3089	.3577	.2069	.3152	.2435	.3190	.2312	1.0132	.4955	.2656	.1914	.5098	.3337	.2276	23	128
.3023	.2998	.2406	.1169	.3876	.2832	.2489	.3624	.2713	.2830	.1888	.2558	.2242	.2731	.1709	.3167	.3476	.2313	.2566	.1816	.2251	.1567	24	133
.1756	.2160	.3625	.0966	.2088	.1181	.2410	.2618	.2519	.1628	.0780	.1426	.1221	.1197	.1369	.1001	.2305	.0836	.1963	.2004	.2312	.0499	25	139
.2441	.1695	.0711	.1975	.1704	.1218	.1908	.1788	.2617	.1767	.1058	.1225	.1731	.906	.1659	.1584	.1365	.0688	.1042	.2296	.1853	.0669	26	150
.3883	.0969	.0458	.2719	.1103	.1351	.1504	.1782	.2318	.1240	.1084	.1062	.1548	.1582	.1108	.2171	.1066	.0435	.0867	.2290	.1156	.0707	27	156
.3790	.0920	.0686	.1327	.0918	.0874	.1284	.2244	.1832	.1262	.0642	.0	.1781	.1261	.1172	.1715	.2049	.0845	.1177	.1978	.0842	.0772	28	161
.3498	.1350	.0742	.1547	.1288	.0903	.1260	.2397	.2011	.0976	.0609	.0990	.1260	.1229	.1074	.1685	.1406	.1113	.1400	.1192	.0789	.0981	30	167
.2345	.0944	.1675	.2304	.0731	.0735	.1507	.2069	.1572	.0919	.0811	.0501	.0778	.0816	.0483	.2135	.1367	.1103	.1013	.2016	.1448	.0287	31	172
.1919	.1284	.3620	.1552	.0502	.1090	.1300	.1744	.1568	.1905	.0893	.0615	.0489	.0560	.0506	.2075	.0987	.0934	.1132	.1729	.1201	.0298	32	178
.1758	.1430	.3730	.1011	.0432	.1059	.1293	.2064	.0991	.1750	.0617	.0662	.0886	.0960	.0626	.2136	.0767	.0726	.1042	.1035	.0589	.0482	33	183
.1656	.1885	.3650	.2407	.1396	.0868	.1530	.2957	.1428	.1105	.0535	.0554	.0911	.0653	.0490	.2047	.0757	.0676	.1099	.1099	.0617	.0504	34	189
.2044	.1049	.3017	.2150	.1920	.0600	.1170	.1934	.1766	.0847	.0775	.0539	.0855	.0548	.0342	.1499	.0816	.0578	.0606	.1730	.0895	.0367	35	194
.2576	.0817	.3230	.2171	.1516	.0698	.1521	.1816	.1451	.0950	.0762	.0697	.0738	.0659	.0448	.1545	.1468	.0583	.0665	.1658	.0976	.0413	36	200
.2129	.0984	.3810	.1854	.0947	.0736	.1428	.0963	.1917	.1110	.0588	.0508	.0961	.0931	.0609	.1692	.1764	.0638	.0300	.1042	.1245	.0384	37	206
.2018	.0946	.3369	.2203	.0557	.0860	.1690	.1264	.2249	.0788	.0766	.699	.0823	.1058	.0817	.1066	.1210	.0765	.0896	.0659	.1862	.0395	38	211
.2022	.0681	.3484	.2076	.0586	.0768	.1702	.1526	.1766	.0965	.0566	.0746	.0631	.0921	.0988	.1715	.0854	.0753	.1202	.0978	.0688	.0207	39	217
.1632	.0554	.2691	.1528	.0559	.0897	.2303	.1256	.1175	.0735	.0348	.0388	.0598	.0758	.1155	.1342	.0677	.0537	.0915	.1107	.0946	.0180	40	222
.1124	.0594	.5181	.1024	.0574	.0581	.0425	.1193	.0951	.0769	.0316	.0256	.0350	.0823	.1106	.1536	.0566	.0299	.0763	.1210	.0375	.0247	41	228
.0860	.0409	.3208	.0735	.0623	.0564	.0438	.0879	.0894	.0948	.0378	.0218	.0356	.0311	.0925	.1074	.0466	.0420	.0552	.0865	.0516	.0283	42	233
.0497	.0628	.3135	.0818	.0598	.0599	.0283	.0698	.0659	.0242	.0166	.0226	.0449	.0349	.0816	.1104	.0833	.0442	.0376	.0547	.1046	.0218	43	239
.0422	.0769	.3140	.1026	.0127	.0723	.0322	.0806	.0704	.0459	.0244	.0193	.0851	.0218	.0869	.1678	.1218	.0552	.021	.0517	.1497	.0250	44	244
.0000	.0487	.3185	.0978	.1076	.0428	.0510	.0881	.1299	.0694	.0081	.0177	.0765	.0378	.0895	.1069	.1595	.0271	.0304	.0510	.1389	.0221	45	250
.0088	.0486	.3103	.0674	.0288	.0987	.0951	.0809	.1890	.0837	.0060	.0581	.0915	.0430	.0639	.0610	.1115	.0268	.0136	.0562	.3901	.0204	46	256
.0986	.0766	.0081	.0281	.3986	.0931	.2210	.0612	.1766	.0398	.0065	.0361	.0956	.0375	.0390	.0115	.0917	.0256	.0000	.0769	.0833	.0191	47	261
.2695	.0857	.0000	.0504	.1876	.0491	.1312	.0000	.1569	.0107	.0131	.0094	.0598	.0276	.0257	.0000	.1066	.0331	.0075	.0363	.0986	.0099	48	267
.2444	.1118	.0000	.0533	.1566	.0000	.0969	.0044	.3293	.0240	.0256	.0000	.0275	.0597	.0487	.0266	.1350	.0260	.0327	.0809	.0768	.0120	49	272
.1928	.1274	.3000	.0591	.0548	.0000	.0728	.0431	.0000	.0092	.0418	.0019	.0171	.0326	.0182	.0307	.1351	.0000	.0771	.1194	.0276	.0164	50	278
.1185	.0691	.8247	.2278	.0660	.0106	.0865	.0828	.0000	.0866	.0518	.0061	.0105	.0186	.0266	.0249	.0607	.0000	.0782	.1124	.0000	.0225	51	283
.1448	.0000	.0241	.0000	.0546	.0412	.0803	.0762	.0213	.0456	.0211	.0133	.0137	.0007	.0165	.0256	.0178	.0231	.0484	.0464	.0000	.0333	52	289
.1230	.0000	.0155	.0020	.0237	.1106	.0362	.0373	.0436	.0365	.0147	.0240	.0001	.0076	.0213	.0311	.0186	.0155	.0124	.0000	.0000	.0318	53	294
.0706	.0043	.0097	.0367	.0059	.1594	.0000	.0208	.1098	.0000	.0081	.0226	.0000	.0155	.0307	.0000	.0552	.0000	.0000	.0000	.0000	.0154	54	300
.0000	.1009	.0000	.0000	.0000	.0938	.0000	.0000	.1274	.0000	.0000	.0232	.0000	.0216	.0036	.0112	.0087	.0072	.0000	.0000	.0171	.0000	55	306
.0000	.1801	.0086	.0000	.0000	.0000	.0000	.0000	.0888	.0200	.0071	.0357	.0000	.0155	.0000	.0594	.0000	.0468	.0000	.0085	.0552	.0000	56	311
.0000	.0918	.0116	.0098	.0000	.0000	.0000	.0000	.0173	.0046	.0147	.0000	.0000	.0000	.0000	.0027	.0000	.0410	.0000	.0048	.0188	.0000	57	317
.0065	.0000	.0000	.0426	.0109	.0000	.0119	.0000	.0000	.0000	.0000	.0000	.0003	.0000	.0000	.0000	.0000	.0353	.0000	.0000	.0000	.0000	58	322
.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0188	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	59	328
.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0078	.0000	.0000	.0000	.0000	.0608	.0000	.0000	.0030	.0000	.0000	.0000	.0000	.0000	.0296	60	333
26.5752	18.9042	11.5039	13.7080	17.0540	15.8391	16.9634	16.9102	16.2571	12.4129	11.4068	11.3358	14.5756	19.8910	18.1654	22.7657	17.9681	15.3223	16.9618	28.0709	27.4065	8.3583	LOG.VAR.	
20.6265	17.3916	13.5670	14.8583	16.5186	15.9193	16.6767	15.4655	16.1280	14.1286	13.5091	13.4675	15.7712	17.8397	16.1817	19.0170	16.9555	15.6577	16.4641	21.1928	20.9367	11.5663	SIG.HGT.	
175	167	125	199	185	181	186	247	245	218	119	151	123	19	117	179	160	1	137	132	111	142	TOTAL OF	
8.4550	8.5985	10.1957	7.8915	8.7580	8.4517	8.2713	7.6980	7.4321	8.1029	9.0358	8.8761	8.5066	9.6859	9.3303	8.3147	8.0283	8.194	9.8037	9.6340	9.8932	8.8879	AVER. T	

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